NOVEMBER PRACTICAL ELE No. 3

The PRACTICAL

ELECTRICAL ENGINEER

A MONTHLY MAGAZINE FOR PRACTICAL MEN

VOL. I—No. 3

NOVEMBER, 1932

IN THIS ISSUE

1/-

GEORGE NEWNES LIMITED

Telephone:
RIVERSIDE, 5151.
(3 LINES)

Contractors to the
ADMIRALTY, WAR OFFICE, POST OFFICE, INDIA OFFICE, ETC ETC

Telegrams:
SAXATILE, PHONE, LONDON

HIGH GRADE
BELL ACCESSORIES
Specialists in
ELECTRIC BELLS
RELAYS
INDICATORS
FIRE ALARMS
BURGLAR ALARMS
BATTERIES

ESTABLISHED 1855

JULIUS SAX & COMPANY LIMITED

MANUFACTURING ELECTRICAL ENGINEERS.

HIGH GRADE
LIGHT ACCESSORIES
Specialists in
WALL PLUGS
PLUG ADAPTORS
LAMP HOLDERS
CANDLE FITTINGS
HOLOPHANE GLASS AND FITTINGS

MORE BUSINESS FOR THE WIRING CONTRACTOR

Has it ever occurred to you that there is an appreciable amount of new business to be obtained by installing Bell Transformers in the houses of those of your customers (and they may number hundreds or even thousands) who are still using batteries for their bell supply? The ideal method is, of course, to fit new bells as well, but, on the other hand, it is quite practicable and perfectly safe to use the existing battery-driven average house-ringing bells, in conjunction with a suitable bell transformer, and for safety, properly fused.

This is just one small item from our large range of manufactures, but if you think it over you will realise that it has possibilities for you from a business-getting point of view. In any case, we should like to send you an interesting pamphlet which we have prepared bearing on this particular subject. Send along to us the Enquiry Form below, and we shall be pleased to forward it to you without any obligation on your part.

TO HELP THE WORKS ENGINEER

We have specialised for years in Electrical Signalling and Safety Devices of all kinds. Whether you are interested in Fire and Burglar Alarms, Inter-Departmental Signalling Systems, or Automatic Safety Devices to protect machinery or users of it—we have much to interest you. Fill in and send to us the Enquiry Form below, or, better still, send us a letter setting out your special problems, and we would be delighted to suggest a method of meeting the particular conditions. No matter how simple or how difficult your problem—we should like to hear from you.

CUT ALONG THIS LINE

ENQUIRY FORM

To JULIUS SAX, LTD.,

27, Lower Mall, Hammersmith, W.6.

Please send me your booklet giving latest technical details relating to the installation of bell transformers with trade list.*

I am also interested in (Place tick against the items)

Relays ....

Fire and Burglar Alarms......................

Lighting Accessories.........................

Visual Signalling ....

*Trade lists can only be sent if letter heading is enclosed.

The PRACTICAL ELECTRICAL ENGINEER

A MONTHLY SURVEY OF MODERN PRACTICE IN ELECTRICAL ENGINEERING

VOL. I NOVEMBER, 1932 No. 3

Published by GEORGE NEWNES, Ltd.,
8-11, Southampton Street, Strand, London, W.C. 2.

Telephone—Temple Bar 7760
Telegrams—" Newnes, London "

Price - 1/- Monthly
Yearly Subscription, 14/- Post Free
6 months' Subscription, 7/- Post Free
Registered for Transmission by Canadian Magazine Post
Canadian Rate: Yearly Subscription, 13/6 Post Free
6 months' Subscription 6/9 ,, ,,

FOLLOWING our usual practice we are publishing in the present issue another article by one of the foremost authorities on electrical work, viz., Mr. A. T. Dover, M.I.E.E., who is Consultant to several large engineering firms, Examiner in Electrical Engineering to the University of London, and Head of the Department of Electrical Engineering at the Battersea Polytechnic. This article deals with Methods of Battery Charging. We believe that this subject has never before been so thoroughly dealt with in a magazine article, and we feel sure that readers will appreciate the value of this for purposes of reference, as it covers practically all standard methods of charging in power stations, private generating plant, stand-by plant for cinemas and theatres, and petrol service stations both large and small.

Why Frequency Control is Important to the Electrical Contractor

Other articles which deal with matters of immediate interest to the engineer who wishes to keep in touch with latest developments are those dealing with the Cathode Ray Oscillograph, and with Methods of Frequency Control in Modern Power Stations. To the man engaged on the retail distribution side of the industry it might appear that frequency control is of rather remote interest, but on the contrary, it is a subject which has a very direct bearing on his everyday work.

There is still an immense market for the sale of domestic electric clocks, which, of course, depend for their accuracy upon the control of frequency at power stations. We propose next month to publish an article dealing in a practical manner with the selling and installation of electric clocks.

The Technical Advice Bureau

We have received hundreds of letters from readers of the Magazine in response to the offer made in the October issue, and our Technical Advice Bureau is now dealing with a large number of queries every day. Every effort is being made to deal with queries promptly, but readers will realise that in certain cases where experts have to be consulted a little time must elapse before a full reply can be sent. As a large percentage of queries are of general interest to electrical engineers we shall in suitable cases publish these together with the replies.

ELECTRICAL CIRCUIT DIAGRAMS

BATTERY CHARGING CIRCUITS

By A. T. DOVER, M.I.E.E.

THE diagrams which follow deal with the various methods of charging accumulators or storage batteries.

Although only a simple fundamental principle is involved in charging any storage battery, the actual charging arrangements are numerous owing to different conditions and circumstances, such as the size and location of the battery, the purpose for which it is employed, the nature of the supply available, etc.

Principle Involved and Requirements to be Met.

When charging any storage battery a certain amount of electrical energy (watt-hours) in the *direct current* form must be supplied to the battery. The charging current must not exceed a prescribed value and its direction must be opposite to that when the battery is discharging. The electrical energy required fully to charge a battery is always greater than the energy discharged from the battery since its previous full charge, because of I^2R losses in the battery during charge and discharge, losses due to leakage or self-discharge when standing, and losses due to the conversion of electrical energy into chemical energy and vice versa.

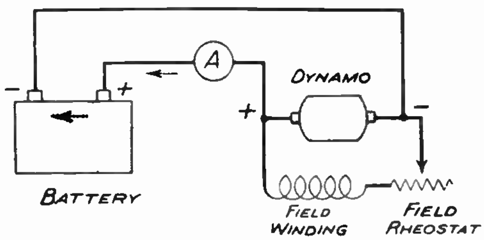


Fig. 1.—SIMPLIFIED CIRCUIT OF CHARGING DYNAMO.

Ampere-hours Instead of Watt-hours.

In practice it is more convenient, when dealing with the charging and discharging of batteries, to consider *ampere-hours* instead of watt-hours. The number of ampere-hours required is equal to the number of ampere-hours discharged divided by the ampere-hour efficiency of the battery (which is the ratio of the ampere-hours discharged and the ampere-hours required to recharge the battery to its previous condition). Thus, if charge and discharge ampere-hour meters were connected in the battery circuit, we should be able to ascertain exactly the charging

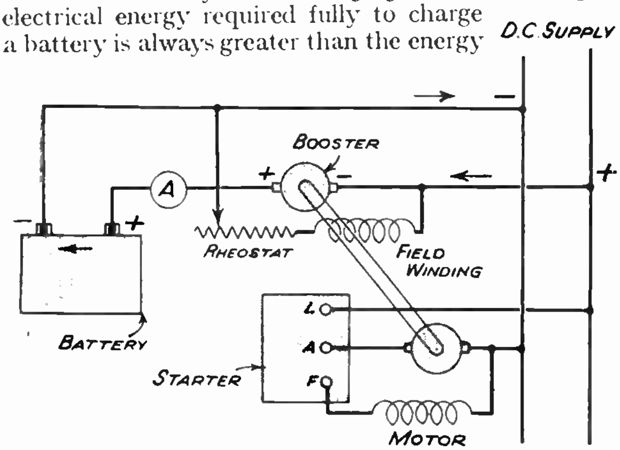


Fig. 2.—SIMPLIFIED CIRCUIT OF CHARGING BOOSTER.

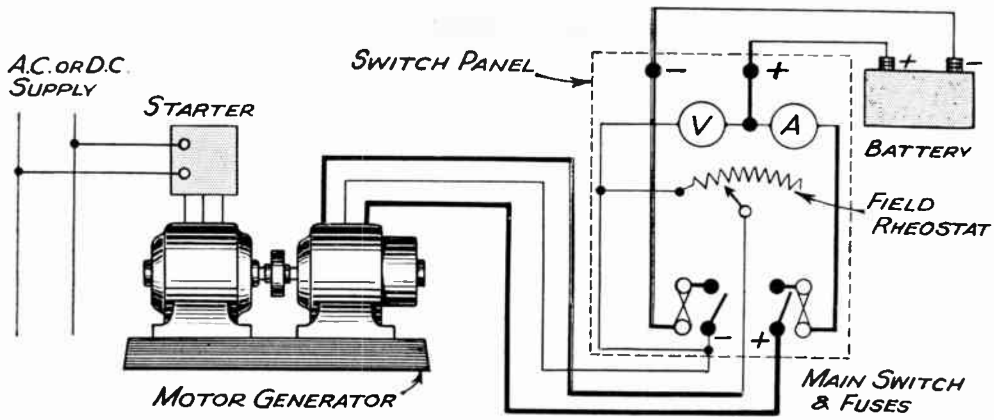
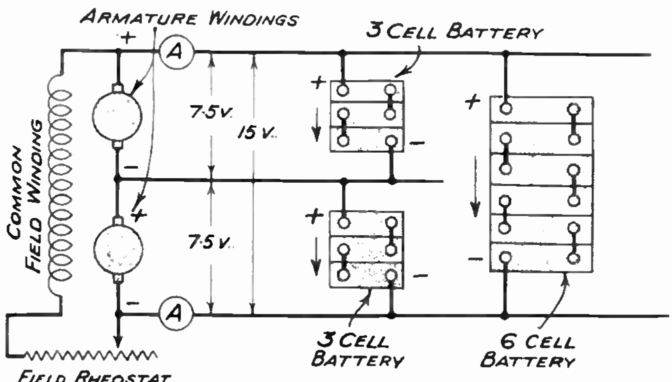


Fig. 3.—Motor Generator Set Arranged for Charging.



(*Left*)

Fig. 4.—Constant Voltage Charging Using Double-wound Generator.

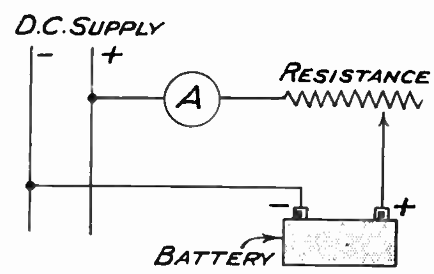
(*Below*)

Fig. 5.—Constant - current Charging from Constant-voltage Mains Using Series Regulating Resistance.

requirements (i.e., the number of ampere-hours required) if we knew the ampere-hour efficiency.

Factors which Govern Ampere-hour Efficiency.

Unfortunately this quantity is generally not known with exactness, as its actual value depends upon the rates of discharge



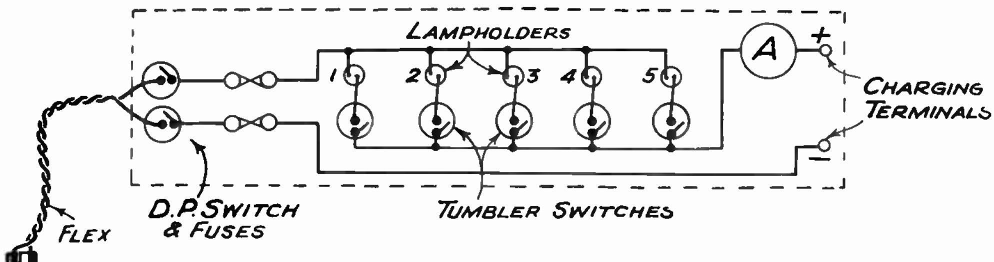


Fig. 6.—Arrangement of "Charging Board" with Lamps as Resistances.

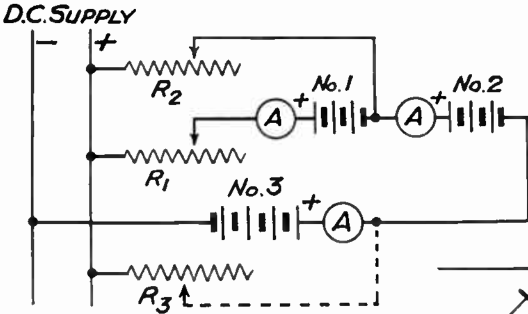
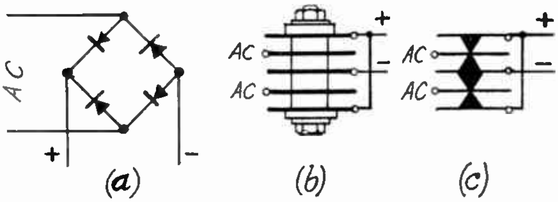
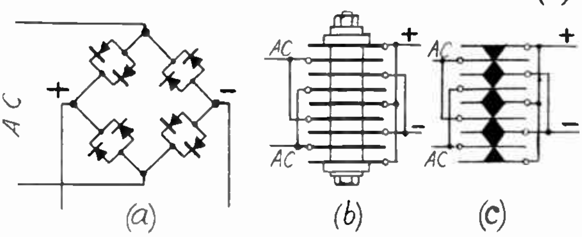


Fig. 7.—Series-parallel Grouping of Batteries and Regulating Resistances for Charging from a Constant-voltage System.

(*Below*)

Fig. 8.—Methods of Representing Bridge-connected Metal Rectifiers. (*a*) Conventional "Bridge" Diagram; (*b*) Actual Arrangement of Elements Showing Terminals; (*c*) Conventional Diagram of Elements in Actual Rectifier (*b*).





(*Left*)

Fig. 9.—Bridge-connected Metal Rectifier with Double Elements. (*a*) Conventional Circuits; (*b*) Actual Arrangement of Elements and Terminals; (*c*) Conventional Diagram for (*b*).

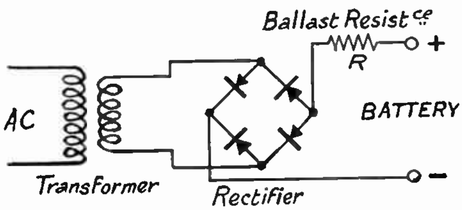


Fig. 10.—Conventional Diagram of Bridge-connected Metal Rectifier with Transformer and Ballast Resistance.

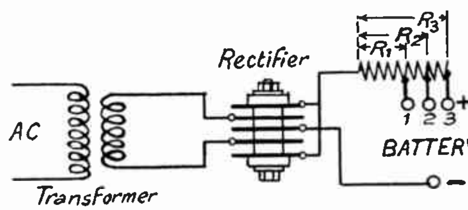


Fig. 11.—Metal Rectifier with Tapped Resistance in Battery Circuit.

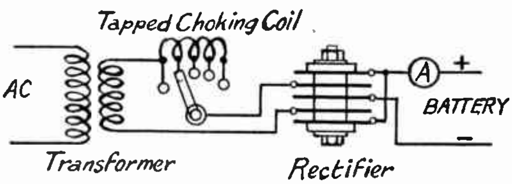


Fig. 12.—Metal Rectifier with Tapped Choking Coil.

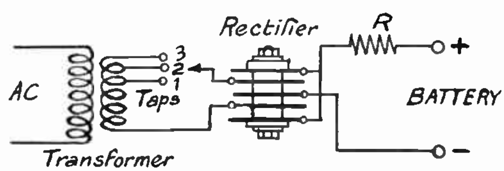


Fig. 13.—Metal Rectifier with Tapped Secondary Winding on Transformer.

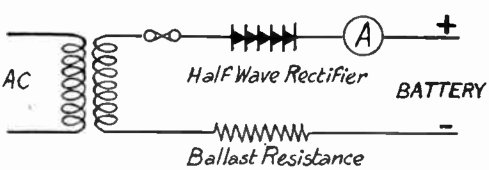


Fig. 14.—Half-wave Metal Rectifier for Medium and High Voltages.

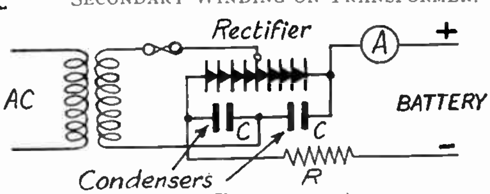


Fig. 15.—Metal Rectifier Arranged for Full-wave Rectification Using the "Voltage Doubler" Circuit. (*Westinghouse.*)

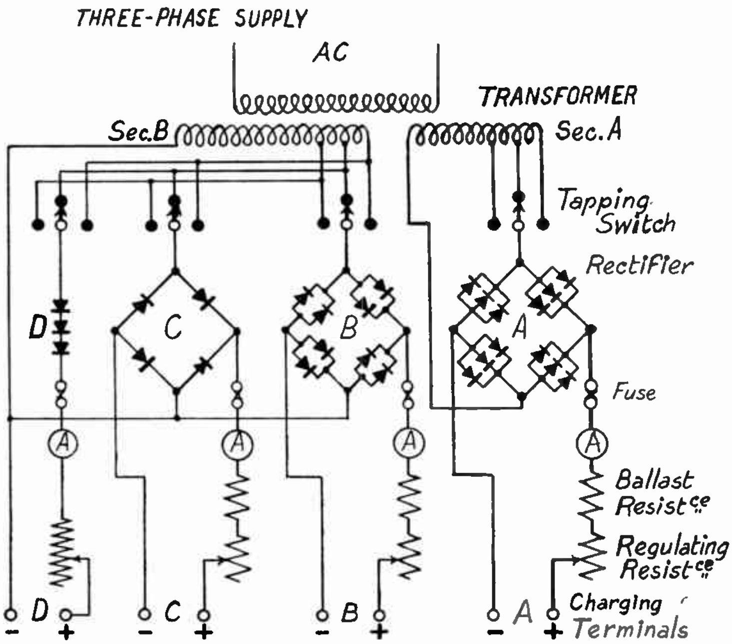


Fig. 16.—Commercial Charging Equipment with Metal (Westinghouse) Rectifiers. Four Different Charging Circuits are Provided, viz.: *A*, for Car Batteries; *B*, *C*, for Portable Batteries, Large and Small Sizes; *D*, for Wireless H.T. Batteries. (*Westinghouse Brake and Saxby Signal Co.*)

and charge, the age of the battery, the condition of the plates, temperature, etc. Hence, when this method is used in practice the meter readings must be taken in conjunction with observations of the specific gravity and temperature of the acid at the end of the charge. The actual values of specific gravity of a fully charged cell vary slightly with the make and design of cell, but the table below gives some which are common.

Charging Current.

The charging current may be supplied at either a constant or a variable rate. In the former case (called *constant current* charging) the current

Table of Values of Specific Gravity.

Temperature °F.	40	50	60	70	80	90	100
Specific gravity (fully charged)	1.258	1.254	1.25	1.246	1.242	1.238	1.234

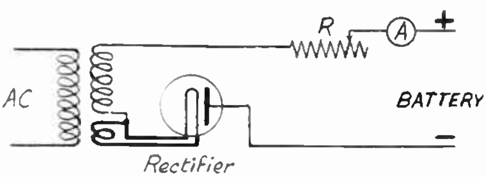


Fig. 17.—Half-wave Valve Rectifier.

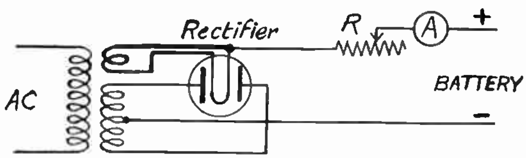


Fig. 18.—Full-wave Valve Rectifier.

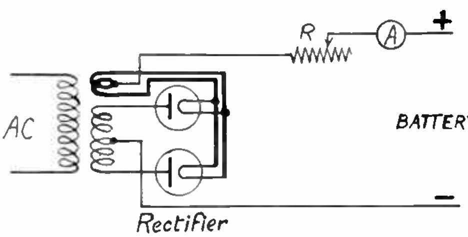


Fig. 19.—Two Half-wave Valves Arranged to Give Full-wave Rectification.

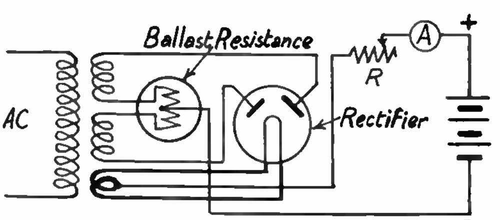


Fig. 20.—Gas-discharge Full-wave Valve with Barretter Ballast Resistance.

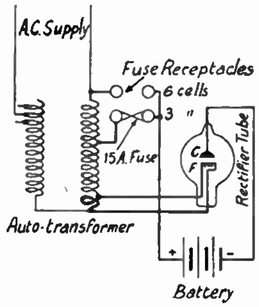


Fig. 21.—SIMPLEST ARRANGEMENT OF ARGON FILLED, HALF-WAVE (TUNGAR) RECTIFIER. (*B.T.-H. Co.*)

is maintained approximately constant by adjusting, from time to time, either the voltage of the charging supply or a variable rheostat connected in series with the battery.

In the second case (called *constant voltage* charging) the charging is effected from a circuit of constant voltage and the current (which has its maximum value at the commencement of charging) tapers off to a low value as the back-e.m.f. of the battery increases.

Trickle charging is a form of constant-voltage charging in which the charging current is much below the normal charging current. This method is intended to compensate for the self-discharge and leakage losses in a fully charged battery which is standing, such batteries being used for emergency supply and for standby purposes.

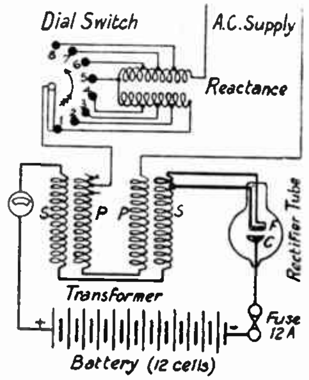


Fig. 22.—TUNGAR RECTIFIER WITH REGULATING REACTANCE. (*B.T.-H. Co.*)

NOTES ON THE DIAGRAMS.

FIG. 1 shows the simplified circuit when a separate dynamo is used for charging. This machine is shunt wound, and the charging current is adjusted to the required value by means of the field rheostat. In practice additional apparatus is necessary for the satisfactory operation of the plant. This apparatus is shown in the complete diagram of connections in Fig. 27.

Circuit with Booster.

FIG. 2 shows the simplified circuit when a booster is used for charging. This method

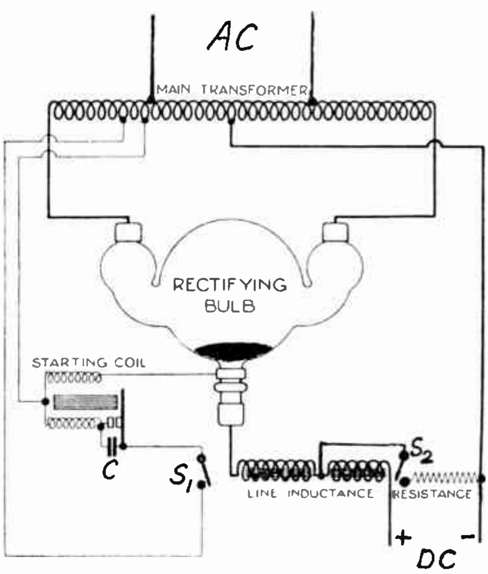


Fig. 23.—SIMPLEST ARRANGEMENT OF MERCURY ARC RECTIFIER FOR SMALL CURRENTS UP TO 5 AMPS. (*Hewittic Elec. Co.*)

S_1, cut-out switch for starting coil; S_2, cut-out switch for excitation circuit.

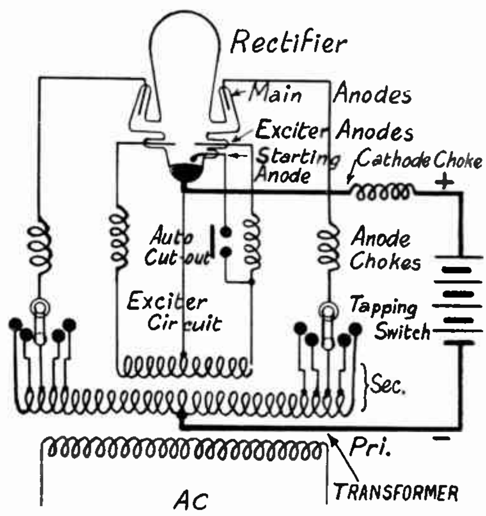


Fig. 24.—MERCURY ARC SINGLE-PHASE RECTIFIER. (*Hewittic Elec. Co.*)

When the exciter anodes come into action the starting anode is cut out by a switch operated by the anode choke.

is employed when a battery is used in conjunction with direct-current generating plant, e.g., as a standby or for load-equalising purposes. The maximum voltage of the booster is equal to : (Maximum voltage required to charge the battery *minus* voltage at the bus bars). Hence the maximum output required from the booster is much lower than that which would be necessary from a separate generator operated according to the method shown in Fig. 1. The complete connections are shown in Fig. 28.

Connections for Motor Generator.

FIG. 3 shows the simplified connections when a motor-generator is used.

Constant Voltage Method with Double-wound Generator.

FIG. 4 shows the simplified connections for a constant voltage method of charging in which a double-wound generator is used to enable two or three voltages to be available at the same time. The machine has two armature windings (each with its own commutator and brush gear) a common armature core, and a common field magnet system with a shunt winding.

Constant Current Charging with Adjustable Rheostat.

FIG. 5 shows how constant current charging may be obtained from constant voltage D.C. mains by means of an adjustable rheostat which is adjusted from time to time to maintain the current at the required value.

Charging Board with Lamps as Resistances.

FIG. 6 shows a simple " charging board " in which lamps are used as resistances for charging low-voltage cells from D C. mains.

Charging Cells Requiring Different Currents.

FIG. 7 shows how a number of cells, requiring different currents, may be grouped for charging from constant voltage D.C. mains.

Elements of a Bridge-connected Full-wave Metal Rectifier.

FIG. 8 shows methods of representing low-voltage bridge-connected full-wave metal rectifiers (copper-oxide or copper-sulphide types) in which a single element is used in each " arm " of the bridge.

FIG. 9 shows how the elements are arranged when currents larger than that obtainable from a single element (Fig. 8) are required. Still larger currents may be obtained by connecting three or more elements in parallel according to this scheme (Fig. 9).

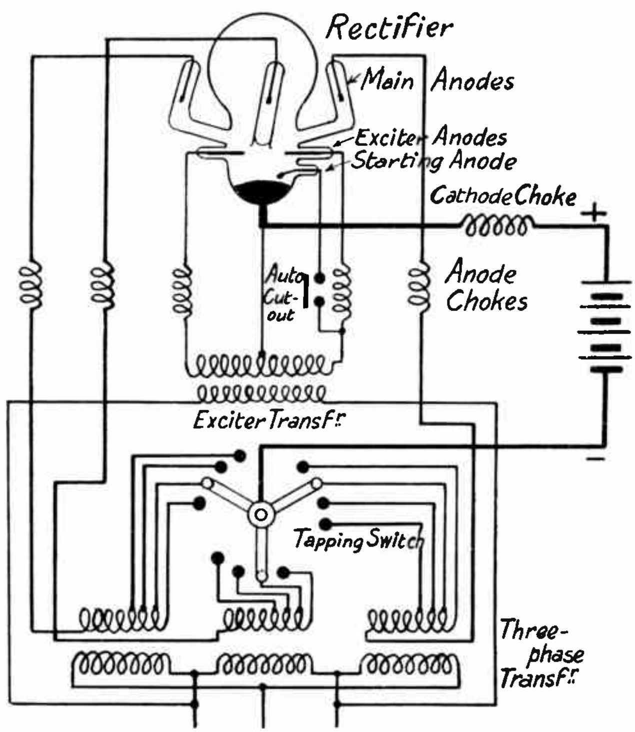


Fig. 25.—MERCURY-ARC THREE-PHASE RECTIFIER. (*Hewittic Elec. Co.*)

Starting and excitation are effected in the same manner as in the single-phase rectifier (Fig. 24).

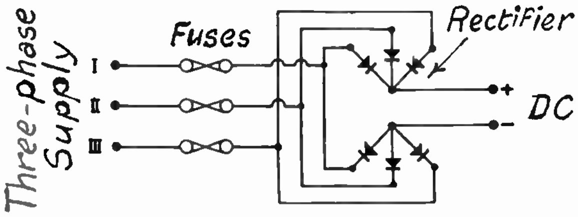


Fig. 26.—SKELETON ARRANGEMENT OF METAL RECTIFIER FOR THREE-PHASE CIRCUIT.

Charging with Valve Rectifiers.

FIGS. 17 to 22 show various charging arrangements with half-wave and full-wave valve rectifiers. The single-valve rectifiers (Figs. 17 and 18) are used for small currents (up to about 120 milliamps.) at medium voltages (50 to 350 volts). The double-valve rectifier (Fig. 19) is used for higher voltages.

Charging With Metal Rectifiers.

Fig. 10 shows a bridge-connected full-wave rectifier arranged for charging.

FIG. 11 shows how the circuit of Fig. 10 may be adapted when batteries of different voltages (e.g., 2, 4 or 6 volts) have to be charged at different times. The resistances R_1, R_2 R_3 must be adjusted to suit the circuit conditions.

FIGS. 12 and 13 show more efficient methods than that shown in Fig. 10. In Fig. 13 the transformer secondary winding is provided with tappings, and in Fig. 12 a tapped choking coil is used. In some cases a transformer with an adjustable core is used.

NOTE.—With all metal rectifiers a ballast resistance or reactance is necessary to prevent overloading the rectifier.

Half-wave Rectification.

FIG. 14 shows how a metal rectifier is arranged for half-wave rectification for charging wireless high-tension batteries.

Full-wave Rectification.

FIG. 15 shows how a metal rectifier is arranged for full-wave rectification for charging wireless high-tension batteries. The elements of the rectifier are arranged in the same manner as those for a half-wave rectifier, but a tapping is brought out from the centre. Full-wave rectification is obtained by means of reservoir condensers (C_1), each of 4 microfarads capacity.

A Commercial Charging Equipment.

FIG. 16 shows how a number of metal rectifiers are supplied from a single transformer. This arrangement is employed in commercial charging equipment for battery service stations, in which batteries of various sizes and voltages have to be charged at the same time.

A Barretter Regulator.

FIG. 20 shows how a full-wave gas discharge valve is arranged with a special ballast resistance lamp (called a barretter) to give a constant current. The barretter

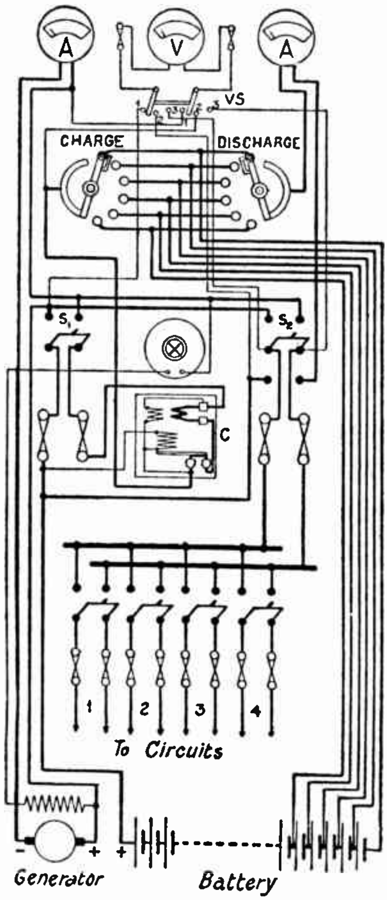


Fig. 27.—ARRANGEMENT OF CHARGING EQUIPMENT FOR COUNTRY HOUSE OR ISOLATED GENERATING PLANT.

consists of a centre-tapped resistance filament in a sealed bulb containing hydrogen, and possesses the property that within certain limits the resistance increases directly in proportion to the current.

Argon Filled Rectifiers.

FIGS. 21 and 22 show half-wave argon-filled (Tungar) rectifiers for charging low voltage batteries at currents up to 5 amps.

Mercury Arc Rectifiers.

FIGS. 23 and 24 show modern single-phase rectifiers. In both cases automatic starting and light load excitation are provided. The smaller bulb (Fig. 23) is started by a high voltage discharge between the mercury cathode and one of the anodes; and is maintained in service at light loads by a resistance connected (automatically) in parallel with the D.C. load.

The larger bulb is started by an auxiliary anode which is provided with either a bimetallic strip or an external electro-

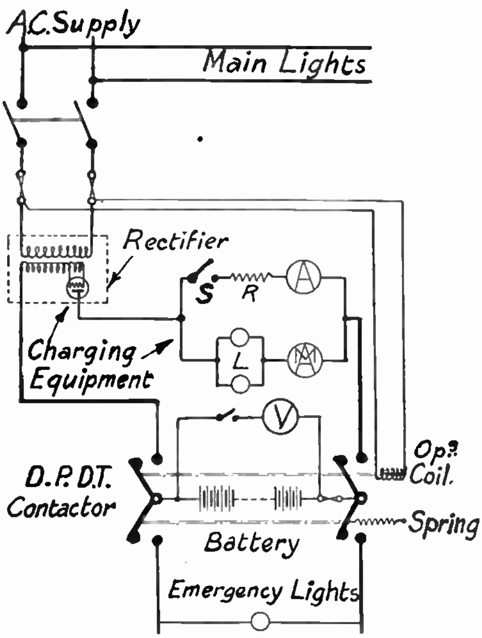


Fig. 29.—CHARGING EQUIPMENT FOR BATTERY SUPPLYING EMERGENCY LIGHTS. (KEEPALITE SYSTEM.)

Trickle charging is effected through the lamp resistance *L*, when the contactor is normally closed. High-rate charging is obtained, when necessary, by closing the switch *S*. (*Chloride Elec. Storage Co.*)

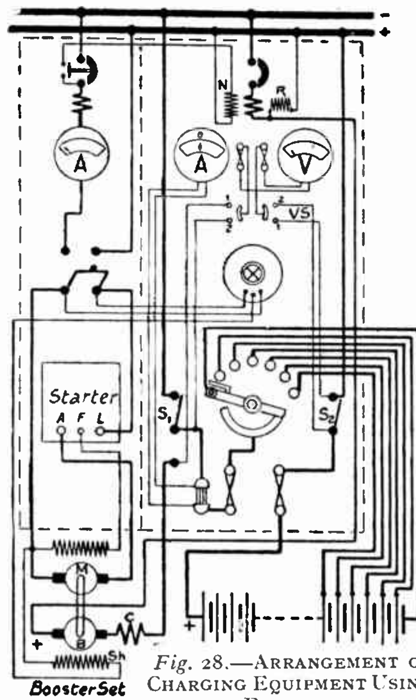


Fig. 28.—ARRANGEMENT OF CHARGING EQUIPMENT USING BOOSTER.

magnet for automatically striking the initial arc. Adjustment of the D.C. voltage is obtained by means of tappings on the transformer.

Country House Lighting Plant.

FIG. 27 shows the full connections of a switch panel for a country house or isolated plant in which a battery supplies the current for lighting purposes. Regulating, or end-cell, switches enable the voltage during discharge to be adjusted. The battery is charged by a shunt-wound generator, and an automatic cut-out C prevents the battery discharging into the dynamo if the voltage of the latter should fall below that of the battery.

Central Station Booster Charging Plant.

FIG. 28 shows the charging arrangements when a battery is used in conjunction with D.C. generating plant. The circuit breaker in the battery circuit is electrically interlocked with that in the motor circuit so that the opening of the motor circuit breaker will trip the battery and booster circuit breaker, thus preventing the booster running as a motor.

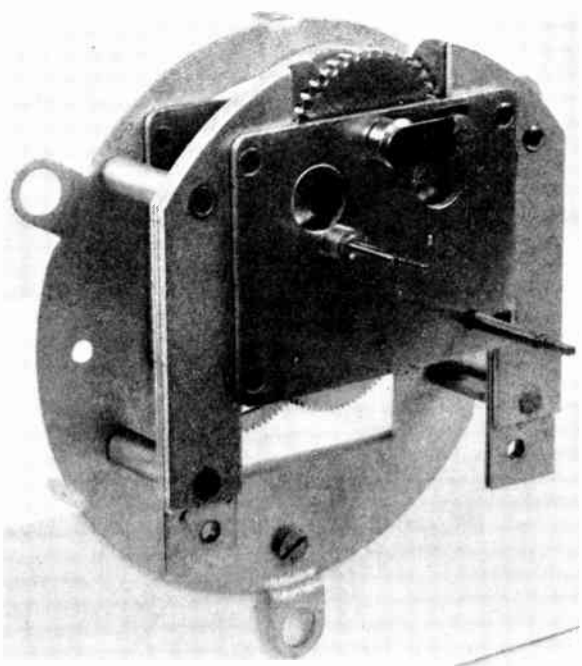
FREQUENCY CONTROL IN THE MODERN POWER STATION

By G. W. STUBBINGS, B.Sc., A.M.I.E.E.

The increasing use of electric clocks makes the subject of frequency control at a power station one of great interest to electrical engineers. In this article Mr. G. W. Stubbings describes the most modern methods of frequency control

OF the many services rendered by electricity in the domestic field that of the provision of accurate time is not the least important. It is not so very long ago that the indication of time in the average household was subject to an error of the order of five minutes. The provision of radio time signals enabled domestic clocks to be set as often as might be desired, but, of course, did nothing to improve their inherent accuracy. The latest system of frequency control, now general in all large power stations, has carried the matter of domestic time indication to what may be considered as the final stage, in that, in all houses connected to a supply system of controlled frequency, an inexpensive electric clock will give time indications with an error of but a small fraction of a minute, and will never require winding or any other attention.

The frequency of an alternating current is a measure of the speed of the generator from which it is derived. The numerical value of the frequency is equal to the product of the number of revolutions per second of the alternator and the number of pairs of poles in the magnet system. The most modern alternators supplying 50-cycle current have a two-pole magnet system, so that the nominal speed of these alternators is 50 revolutions per second, or 3,000 r.p.m.



THE ROTOR AND STATOR OF THE FERRANTI ELECTRIC CLOCK.

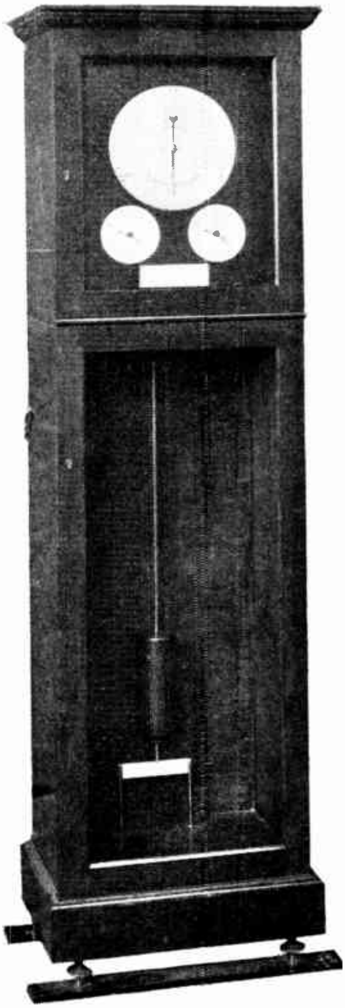
Note that the stator pole is serrated and serrations are made in the rotor of a slightly different pitch. The yoke of the rotor has been removed, together with the stator coil. The stator coil only is energised from the supply mains and when the rotor disc is spun round it automatically falls into step with the frequency of the supply. This is the type of clock used in thousands of homes to-day.

Adjustment of Governor Control.

The speed of an alternator depends upon the load it is carrying and the governor control. This control is adjustable from the switch room of the power house, and it is by means of adjustment of governor control that correct allocation of the total load between several generators is carried out. If two alternators are operating in parallel, an adjustment of the governor control of one of them, tending to increase the speed, will cause this machine to carry a greater fraction of the load. Unless, however, another adjustment is made to the governor of the second machine, the frequency of the system will rise. Frequency is thus controlled from the switch room of the power station.

Speed of the Prime Mover.

Frequency, as we have seen, is primarily a function of the speed of the prime mover, and its true values are instantaneous. We can, however, visualise an average value of the frequency as the ratio of the number of revolutions of the prime mover, executed over a considerable period, to the time of this period. Thus the average frequency of a power supply over one day would be measured by the total number of revolutions of the prime movers executed during this day. If the average frequency were constant, then the number of revolutions per day would also be constant. It is also easy to see that, with constant average frequency, the number of revolutions executed by the generators will be a measure of time.



Latest Type of Everett Edgcumbe All-electric "Synclock" Master Frequency Meter.

With impulse driven standard clock as used in power stations The lower left-hand clock dial is driven by a synchronous motor and the right-hand clock dial is an electromagnetic impulse type clock movement.

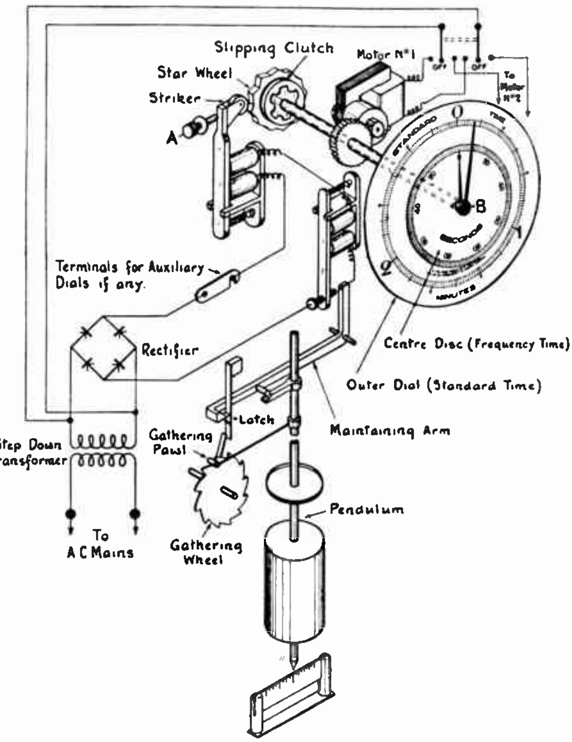
The Synchronous Motor.

It is a fundamental property of a synchronous motor that its revolutions are executed exactly in step with those of the generator supplying it. If the motor and the generator have the same number of poles in the magnet systems then the revolutions they perform when electrically connected will be exactly the same over any period, however long. By counting the revolutions of a synchronous motor it would thus be possible to measure the average frequency of a supply at any point of the system. Conversely, if the average frequency were known to be constant, the counting of the revolutions of the synchronous motor could be used to measure time.

This principle is utilised in the ordinary clock, as here we have a spring or weight-driven motor which is constrained to work in exact synchronism with a pendulum or balance having a constant and standard frequency. A synchronous motor, geared to a clock, could, therefore, on a system of constant frequency, be utilised to indicate time in the usual way.

The Warren Synchronous Motor.

This idea has been practically realised by the invention of the small synchronous motor, first associated with the name of Warren. The Warren motor consists of an electromagnet the poles of which are fitted with shading rings, to give a rotating field. The rotor consists of an iron disc, which, due to the action of the rotating field and to its own magnetic hysteresis, is constrained to rotate in exact synchronism with the supply. The rotor is geared down to a spindle which makes one revolution per minute. The whole motor with gearing measures only about 2½ in. square, and consumes about 4 watts. Such a motor can be easily incorporated into an ordinary clock case. A clock of this kind will indicate correct time when operated from a supply system the frequency of which is maintained at an exact average value.



GENERAL ARRANGEMENT OF EVERETT EDGCUMBE MASTER FREQUENCY METER WITH IMPULSE-DRIVEN CLOCK.

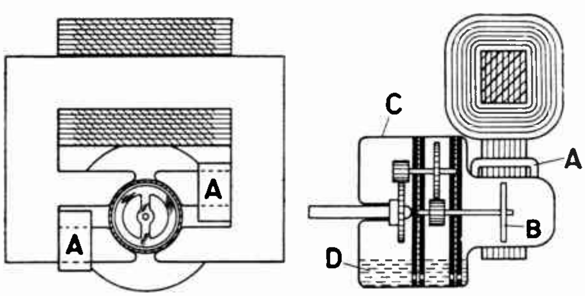
Duplicate motors with a change-over switch are provided for driving the frequency disc and time hand.

The impulse electromagnets are supplied with direct current (at about 12 volts), which is obtained from a rectifier and a step-down transformer.

Instruments for Indicating Frequency.

Ordinary instruments for indicating frequency depend for their action on either electrical or mechanical resonance. They inherently give instantaneous values. In other words, their indication is a measure of the instantaneous speed of the alternator from which they are supplied. The possible error of these instruments is of the order of 1 per cent.

Suppose that the frequency of a power supply, controlled by means of the readings of indicating frequency meters, were maintained with an error of one half of one per cent. The error of a synchronous motor clock connected to this system would be the same as the error in the frequency. Since there are 1,440 minutes in one day, the clock would gain or lose about seven minutes per day. Now an error of frequency control by indicating instruments of the order suggested is one which might easily arise, while an error of seven minutes a day in a clock would be intolerable. It is thus clear that the control of frequency by indicating instruments cannot be accurate enough for time service.



SECTION THROUGH THE SYNCLOCK (WARREN) MINIATURE SYNCHRONOUS MOTOR, WHICH MEASURES ABOUT 2½ IN. SQUARE.

A, shading rings producing a rotating field. B, steel disc drawn round thereby. C, brass housing protecting the gearing and forming an oil bath, D.

Control of Average Frequency.

The final solution of the problem of using an alternating current system for time service is found in the control, not of instantaneous, but of average frequency. This is carried out in a very simple way. Suppose in the control room of the power station there are two clocks installed side by side, the one driven by a synchronous motor supplied from the system and the other a standard instrument which gives absolutely accurate time. Then all that is required to maintain correct average frequency is that the speed of the prime movers is so adjusted that the readings of the two clocks are always the same. Since all synchronous motor clocks move at exactly the same speed, the error of any clock on the system, if initially set correctly, will not exceed that of the motor clock in the control room of the power station.

In the Warren master frequency meter there are two concentric pointers, the one driven by a synchronous motor and the other from an accurate master weight-operated clock. The pointer of the standard clock makes one revolution in three minutes.

How the Control is Effected.

The control of the average frequency of the system is effected by so regulating the speed of the prime movers that the pointer driven by the synchronous motor never deviates by more than a few seconds from that driven by the standard clock. The difference between the control of average frequency and the maintenance of a constant instantaneous frequency cannot be too clearly grasped.

With a controlled frequency the instantaneous frequency may vary considerably due to putting machines into, or taking them out of, service, or due to the action of the governors of the turbines at certain loads. Such fluctuations do not necessarily affect the average frequency. All that the operator has to do is to arrange that the total number of revolutions of the prime mover and of the clock motors, executed from the time when the controlled system was inaugurated, corresponds to the correct value.

Only Very Occasional Adjustment Necessary.

When the system of controlling frequency was first suggested, control room operators anticipated that considerable difficulties would be experienced in maintaining the system time, as indicated by the motor clock, at a value not differing by more than a few seconds from the correct value. It was thought that, unless the prime mover speeds were constantly being adjusted, the system time would fluctuate by considerable amounts from the true time. This was not found to be the case, and the required accuracy of the system time can be maintained by very occasional adjustment of the governor control of the prime movers. A little thought will show that this is the case, as an error of 1 per cent. in the frequency will only build up an error of three seconds in the system time in a period of five minutes.

The fluctuations in the system time are thus accumulated gradually, and very soon the operator can judge the adjustment required to correct a tendency for the error of the system time to accumulate in any direction. The adjustments to the governor control will naturally depend upon the known conditions of load variation. If, for instance, system time were a few seconds fast at a time when the load was increasing the operator would probably rely on the reduction of frequency consequent on the load increase to correct the time. If, on the other hand, the system time were slow at a time when the load was increasing, a slight adjustment of the prime mover speeds would be called for.

Automatic Control Not Justified.

At the time that the control of frequency was first developed, suggestions were put forward for automatic gear to maintain the speed of the prime movers at the correct average value. There would be no great technical difficulty in carrying out such a suggestion. Experience has, however, shown that manual control of frequency is so efficient and so easy, that the additional complication of apparatus for automatic control could not be justified.

THE QUASI-ARC SYSTEM OF ELECTRIC WELDING

By H. S. MARQUAND

No method of joining, strengthening or repairing metallic structures is more simple or efficient than the process of electric arc welding. In this article will be found some practical advice regarding the installation and operation of the Quasi-arc system

FOR many years the metallic arc process developed along the lines of using bare or lightly coated mild steel electrodes and indeed even to-day such electrodes are used to a considerable extent, unfortunately too often to the detriment of the electric arc welding progress.

The inventor of the Quasi-arc Electrode was probably the first to realise that the ultimate success of electric arc welding would depend upon the ability to provide an electrode which was based on scientific metallurgical and chemical lines in order to ensure the deposition of a metal which is free from defects caused by oxides and nitrides and other impurities, and that the deposit would possess the physical and chemical properties of the metal parts being welded.

The Electrical Equipment.

In order to obtain the best results it is essential that the welding equipment should be capable of giving a stable arc at the correct amperage for the electrode in use.

Electrical Connections.

The diagram of electrical connections of a special welding generator is shown below. The current for welding is regulated by means of a radial switch which gives four progressive ranges of output in conjunction with a field regulator for the necessary finer control.

The Field Regulator.

The field regulator is arranged as a separate unit which the operator can keep at his side when at work.

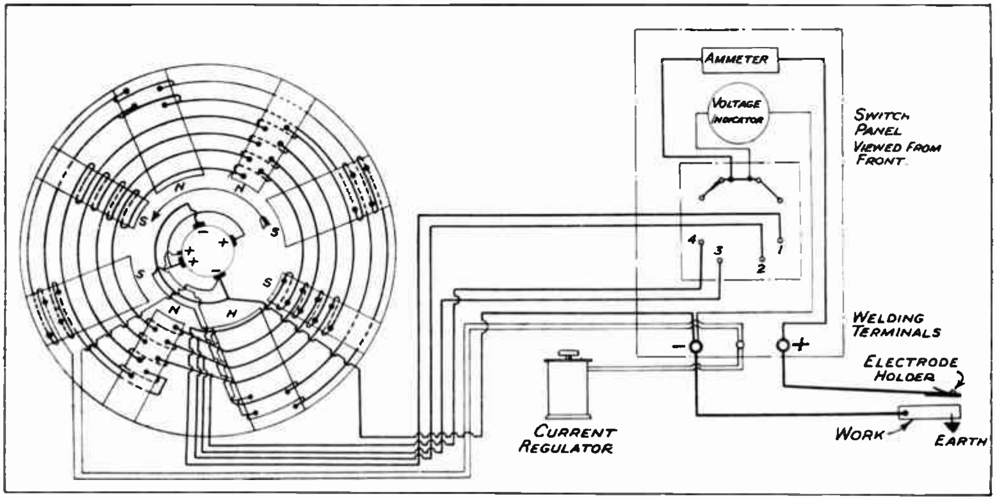
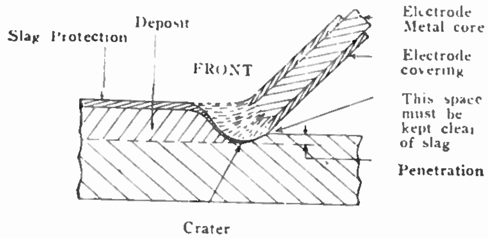


DIAGRAM OF CONNECTIONS FOR "QUASI-ARC" SINGLE-OPERATOR WELDING GENERATOR.
The current for welding is regulated by means of a radial switch giving four progressive ranges of output.



HOW THE TIP OF THE ELECTRODE SHOULD BE KEPT JUST BELOW THE SURFACE OF THE SLAG.

Working Off A.C. Mains.

If it is desired to work direct off alternating current mains a specially designed welding transformer and inductive current regulator can be used. These transformers can be built for single or multiple phase supply, and can be arranged for two or more operators.

The internal arrangement of the special current regulator is shown in the diagram.

Other Equipment Required.

In addition to the welding machine, it is advisable to provide :—

1. A steel plate, say, 3 ft. by 2 ft. by ⅜ in. thick, resting on a bench or iron trestles at bench height.
2. Suitable lengths of trailing cable.
3. Portable screens about 6 ft. 6 ins. high covered with asbestos cloth painted green or with lamp black.
4. A portable drill and grinder.
5. Convenient lifting gear.
6. A supply of clamps, copper strips for backing up a weld if required.
7. A steel straight edge.
8. A hand and face shield fitted with a special coloured glass window, for welding.
9. A hand shield fitted with a clear window, for chipping.
10. An electrode holder with five yards of special flexible welding cable attached.
11. A pair of leather gauntlet gloves.
12. An ammeter and voltmeter.
13. A chipping hammer.
14. A wire scratch brush for cleaning the weld.
15. An earthing clip for connection of supply cable to work to be welded.

Connecting Up Cable From Plant to Job.

The negative cable from the welding generator or source of welding current should be connected to the table or plate by means of a clamp or bolt. The plate should be efficiently connected to ground.

The regulator should be in a position convenient to the operator's hand, in order that he can make fine adjustments of the welding current without having to move far from his working position.

Connecting Electrode to Current Supply.

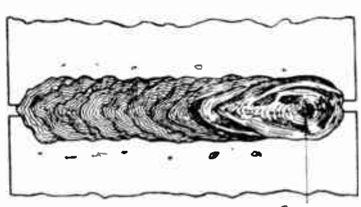
Connect the socket on the electrode holder cable to the plug on the regulator or to the positive terminal on the control panel of the machine, as shown.

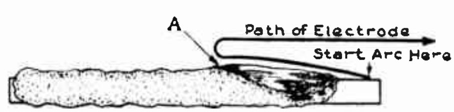
Adjusting Welding Current.

Now grip the bared end of the electrode chosen for the job on hand in the holder and adjust the welding current, as recommended by the makers according to the diameter of the electrode and the class of welding. This is done by means of the four pole control switch on the control panel at the machine, or by turning the handwheel on the regulator if using A.C. equipment, to the required stop.

STRIKING AND MAINTAINING THE ARC.

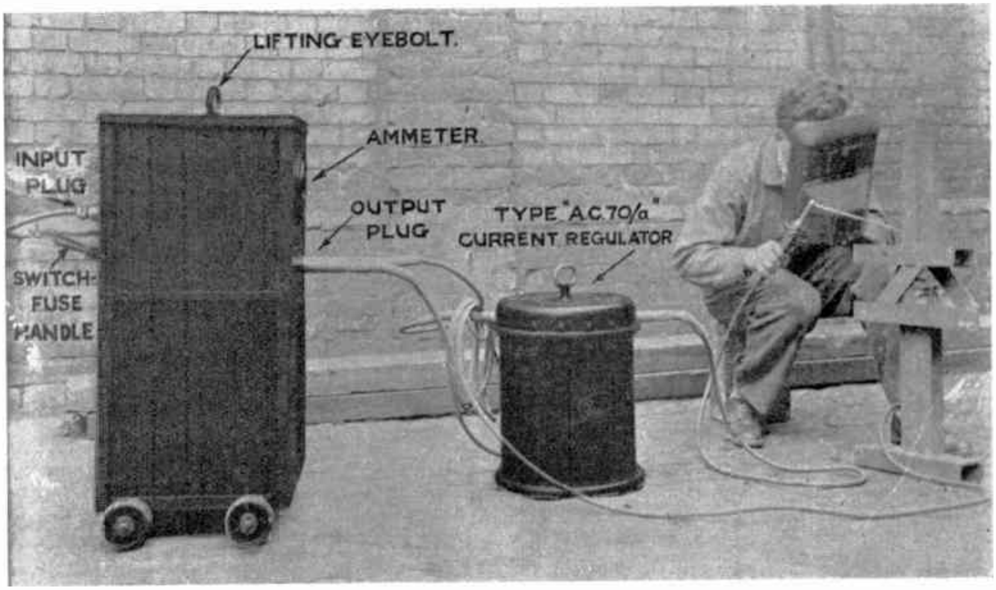
Having connected up the machine, adjusted the current to about 85 amperes (assuming that we are going to commence welding with a No. 10 gauge electrode) and placed a piece of, say, ⅜ in. steel for practice in good contact with the welding





HOW TO RECOMMENCE WELDING WHEN AN ARC IS BROKEN.

Strike the arc about ¼ in. to ⅜ in. in front of the crater and travel quickly back over the crater and then forward again at the normal rate of progress.



THE QUASI-ARC SINGLE-OPERATOR WELDING GENERATOR CONNECTED UP FOR USE.

AN IMPORTANT APPLICATION OF ELECTRIC WELDING IS THE REPAIR OF RAILWAY TRACK.

This shows a welding operator in position, ready to strike the arc.

bench, we are all set to commence operations. Now take the welder's hand screen (with the coloured window) and be careful to hold it in front of the face well down to the work before striking the arc. The electrode holder should be gripped lightly in the right hand with the electrode pointing down to the work at an angle of about 45 degrees.

Position of the Welder.

Successful welding depends very largely upon the position taken up by the welder. The operator, whenever possible, should sit to his work, and, resting his left arm on the table or work, hold the hand screen over the arc. The right arm is best held close to the side and the muscles of the arm and wrist well relaxed, so that the manipulation of the electrode holder is a free natural movement of the wrist.

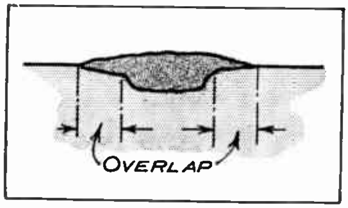
How To Strike the Arc.

To strike the arc, lower the tip of the electrode down to within about $\frac{1}{4}$ in. of the work at a point where it is required to weld and then with the face protected by the screen, touch the work as though striking a match, but only removing the electrode tip in an upward direction about $\frac{1}{8}$ in. An arc will then start between the electrode tip and the plate and immediately the electrode end will commence and continue to burn away and will be deposited in the form of beads upon the plate.

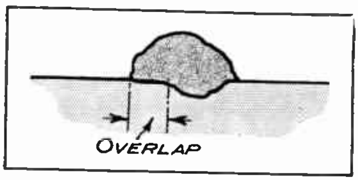
How To Maintain the Arc.

In order to keep the arc going it is necessary to feed the electrode down at the same rate that it is fused by the current in the arc.

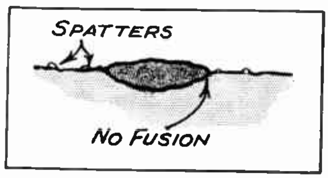
When confidence is gained in striking the arc, the next step is to maintain the arc until a whole electrode is run out and to practise keeping the arc as short as possible.



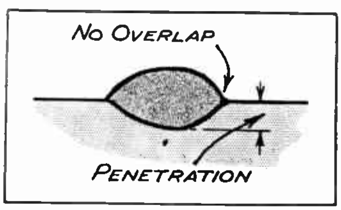
Welding arc has travelled along too slowly.



Not enough heat used.



Too long arc used or too rapid travel.



A satisfactory weld.

CROSS SECTION OF BEADS DEPOSITED UNDER DIFFERENT CONDITIONS.

How the Electrode Burns Away.

With quasi-arc electrodes the special covering burns away in such a manner that a sleeve of insulating slag is maintained about $\frac{1}{8}$ in. beyond the end of the metal core. If this sleeve is kept slightly touching on the work, the arc will be about $\frac{1}{8}$ in. long inside and will be protected the whole time from the atmosphere.

Practice in Laying Down Deposit of Metal.

The deposit of metal from the electrode should be laid down, for practice, in smooth straight runs of various lengths from one electrode, each run being of an even thickness and width of metal throughout.

JUDGING CORRECT VALUE OF CURRENT.

The question of the correct amperage to use for various gauges of electrodes is one which would seem important to the beginner.

It is not possible to fix a standard current density, as the amount of amperage will vary with the thickness and mass of the work being welded, the type of joint, and position of the work relative to the electrode. Generally speaking, the thicker or heavier the work the higher the current that will be required with a given size electrode.

The correct current is when the metal from the end of the electrode flows freely

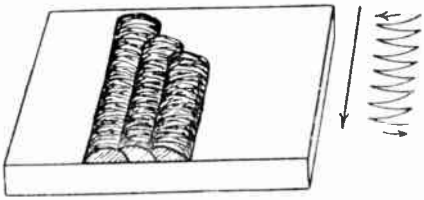


DIAGRAM OF WELD SHOWING DEPOSITED METAL AND THE DIRECTION OF POINT OF ELECTRODE.

When reinforcing a surface the second and subsequent runs overlap each previous one.

and at the same time effects good fusion.

What Happens When Current is Too Low.

If the current is too low, the arc will be sluggish and difficult to maintain, the metal will pile up without penetrating the metal of the work, and difficulty will be experienced in keeping the slag from the electrode mobile.

Current Too High.

On the other hand, if the current is too high the arc will be fierce and splutter and the metal will flow too freely from the electrode to be controlled.

JUDGING THE ARC.

The welder should, before attempting serious welding jobs, be thoroughly conversant with his welding arc and the behaviour of the electrodes and the coating thereon.

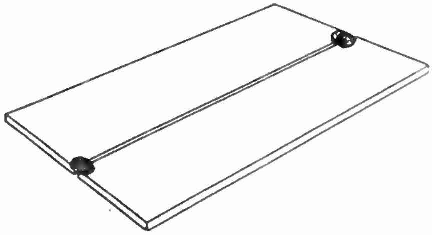
Sense of Touch.

By keen observation the welder will be able to develop a real sense of touch and a sense of colour, which are both invaluable to expertness in manipulating the welding arc.

What Happens to Metal at Arc.

When watched through the screen window, the molten metal at the arc will appear dull red and the molten slag a bright red.

Where the arc strikes the work the metal will become molten. Due to the gyratory action inherent in the quasi-arc this pool of metal will be agitated. The metal



TACK WELDS AT ENDS.

deposited from the electrode will be intimately mixed with the fused area. The colour of the metal around this spot will gradually shade off until it finally becomes black at a short distance from the arc. The colour shades indicate the temperature of the metal.

To Get Maximum Amount of Fusion.

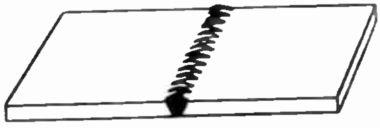
The aim of the welder should be to distinguish for a certainty the different temperatures and concentrate his arc at the hottest spot in order that the parent metal and the deposited metal will be well fused and united.

It will be found possible to keep the tip of the electrode just below the surface of the slag covering all the time and by deft movements of the wrist to keep the slag floating just ahead of the arc. The welder should concentrate on the hot metal in the crater, filling it with deposited metal as the process of welding proceeds. To facilitate this the electrode is inclined forward pointing into the crater which will then automatically follow the movement of the arc.

Breaking the Arc.

The arc must never be broken suddenly, for if this is done the hot metal in the crater will quickly cool and contract and entrap air, gas or particles of slag which are dissolved in the hot metal and which will not have time to be set free before solidification takes place. Each time the arc is sharply interrupted a weak porous spot is left in the weld.

The correct way to break the arc, that is, to stop welding in order to replace a new elec-



APPEARANCE OF GOOD RUN OF WELDING JOINING TWO PIECES OF $\frac{1}{8}$" OR $\frac{3}{16}$" PLATE.

trode or for any other reason, is to gradually lengthen out the arc, at the same time gradually travelling the arc back over the welded metal. In this way the crater is filled with deposited metal before the heat is suddenly interrupted.

How to Recommence Welding.

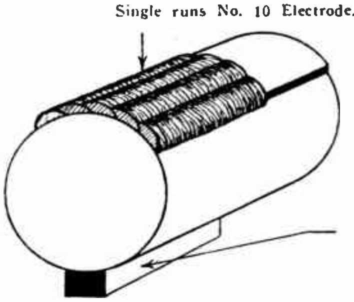
When an arc is broken care should be taken in recommencing to close the gap in the deposited metal and also to guard against leaving a lump of metal on the bead. Strike the arc about ¼ in. to ⅜ in. in front of the crater and, keeping a very close arc, travel quickly back over the crater, then move the arc forward again at the normal rate of progress.

Speed of Travel.

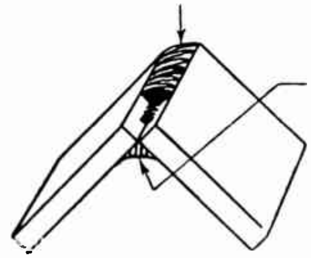
The correct welding speed is closely linked up with gauge of electrode, current used and arc length, width and height of deposit required. However, the chief thing to aim at is good penetration while using the closest possible arc. The appearance of a bead deposited under different conditions is shown and should be studied carefully and results of actual deposited beads compared with the sections shown.

FURTHER WELDING PRACTICE.

When the welder can hold and maintain a close arc and can deposit a neat uniform single bead of metal, the next step is to chip and brush away thoroughly all slag covering a run of metal and deposit successive runs of metal parallel with the first one. Each successive run should



THE BUILDING UP OF METAL TO REPRESENT THE REINFORCEMENT OF A WORN SHAFT.
This also shows the building up of a solid feather or tooth.



TWO PIECES OF ⅜ IN. PLATE FORMING AN ANGLE CORNER, PARTLY WELDED.

overlap about one third the width of the previous bead, so that a regular and uniform surface is obtained.

Varying Width of Deposit.

The width of the deposited bead can be varied as desired by a gentle side to side motion of the arc.

Removing Traces of Slag from Weld.

Having so deposited several beads, all traces of slag on top of the weld should be removed. With quasi-arc electrodes this is easily and quickly done by a few blows with the chipping hammer, followed by brushing.

Depositing Layers of Metal.

Next deposit layers of metal, covering that already laid down, taking great care that each successive layer of metal is well fused into the previous layer, thereby removing the possibility of slag inclusions in the deposited metal.

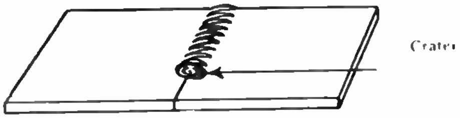
JOINING TWO PIECES OF PLATE.

Not until the welder is really proficient in the work already described should the joining together of two plates (butt welding) be attempted.

Butt welding presents an entirely new difficulty to the beginner, as it now becomes necessary to watch the butting edges of both the plates to ensure that these are effectively fused and thoroughly united by the deposited metal.

Preparing the Two Plates for Welding.

The two pieces of plate to be joined (start off by joining two pieces of flat ⅜ in.

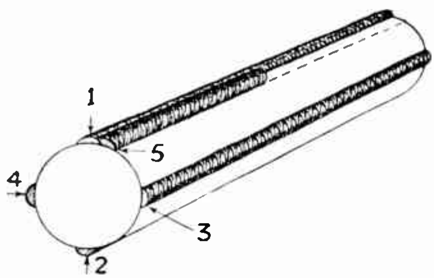


Two Pieces of $\frac{1}{8}$ in. Plate Partly Welded.
Plate edges not bevelled but set $\frac{1}{16}$" open.
Note penetration at crater.

plate) should first be bevelled and laid parallel with one another, with their bevelled edges set apart about $\frac{1}{16}$ in. A tack weld is made at each corner.

The First Run of Metal.

A run of metal, using a No. 10 gauge electrode, is now made along the bottom of V so made. This first run of metal in making a butt joint is extremely important. Make certain that the deposited metal projects slightly through on the underside of the joint.



Reinforcing Worn Shaft.
New metal deposited in runs parallel to axis of shaft in order shown.

The Second Layer.

The next step is to chip and brush the run of weld metal and deposit a second layer with a slight lateral movement of the electrode, so as to distribute the heat on both edges of the plate.

The Finishing Run.

The finishing run should overlap the two plate edges by about $\frac{1}{8}$ in. on each side.

Testing the Welded Joint.

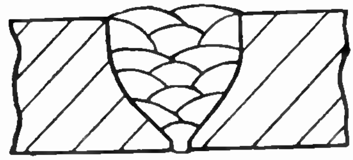
The welded joint should now be gripped in a vice with the parallel edge of the weld down on the jaws of the vice and the top half of the plate given a few sharp blows with a hammer. The behaviour of the welded plates will be a very good indication of the quality and success of the weld.

A Likely Fault—

First attempts at butt welding usually show that all the penetration is on one side only and that the deposited metal from the electrode is welded to one plate bevelled edge only. Practice and patience will overcome this difficulty however.

—and How to Avoid it.

The effective fusing of the two edges of



Order of Butt Welding Thick Plates.
Fill in bottom of V with No. 10 electrode, following on with several successive layers with No. 8 electrode. Finishing top layer can be No. 6 electrode.

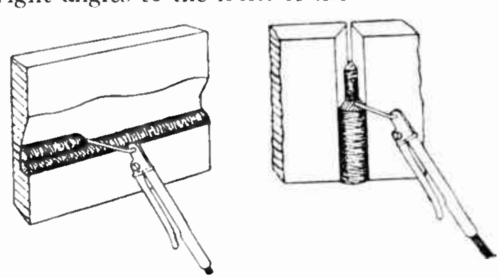
the plates is obtained by alternately pointing the tip of the electrode from one side to the other in a slow lateral movement, but pausing rather longer on the plate edges and moving slightly quicker over the hot deposited metal.

Butt Welding Heavier Plates.

Heavier sections of plate can be butt-welded.

In this case the first run at the bottom of the V joint must be made with a No. 10 gauge electrode, using 75 to 80 amperes, and succeeding runs with a No. 8 gauge electrode and 110 to 115 amperes. Larger gauge electrodes and higher currents can of course be used for the finishing runs of very heavy welds.

Before commencing to weld the plates together they should be set up in such a position that the line of the joint is at right angles to the front of the welder and



Procedure for Vertical Welding.
Note inclination of electrode.

the weld should be started at the end farthest away from the operator.

LAP WELDS.

A lap weld is one in which the edges of two plates are overlapped and the welding material is so applied as to bind the edge of one plate to the face of the other plate. The weld so formed is of triangular section. To give the maximum strength as regards binding the two plates together, the vertical height of the weld should be equal to the horizontal length of the triangle. A " fillet " weld is so formed, and is a type of weld which is extensively used in arc welding procedure.

T Joint Lap Weld.

A T joint, which occurs when two plates have to be welded at right angles to each other, is made by applying fillet welds. The weld may be made with either a single fillet weld or with a double fillet weld, that is a fillet weld along both sides of the vertical plate at its junction with the horizontal plate.

Setting Up the Plates.

When making a fillet weld with quasi-arc electrodes, the two plates are set up in the correct position and a tack weld is made to hold the plates in secure alignment.

Electrode and Current Required.

Start the weld at the end of the joint away from the operator, using a No. 10 gauge electrode, and about one-fifth more current than would be employed for a butt weld, say, 90 amperes.

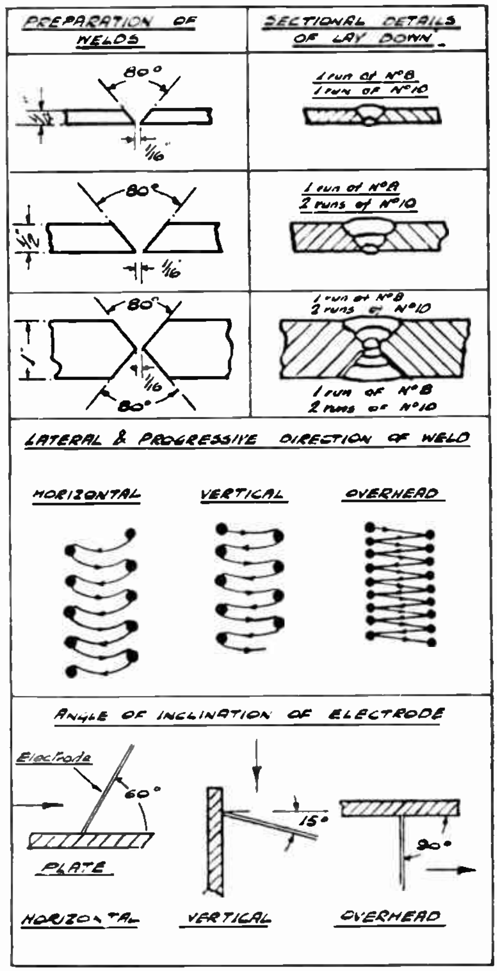
Making the First Run.

A sealing run is now made by striking the arc in the far corner of the abutting edges and keeping a very short arc (nearly touching the plate) to ensure good penetration and to counteract the tendency of the molten slag to run ahead of the electrode tip. Draw the arc along the apex of the joint at a uniform rate.

This sealing run is of very great importance. If perfect penetration is not obtained right along the two abutting plates, a nick will be left which amounts to an initial fracture, thereby weakening the weld against loading stresses, particularly when the weld is to be subject to bending.

Completing the Fillet Weld.

The fillet weld can now be completed by



HOW THE PLATES TO BE JOINED SHOULD BE PREPARED.

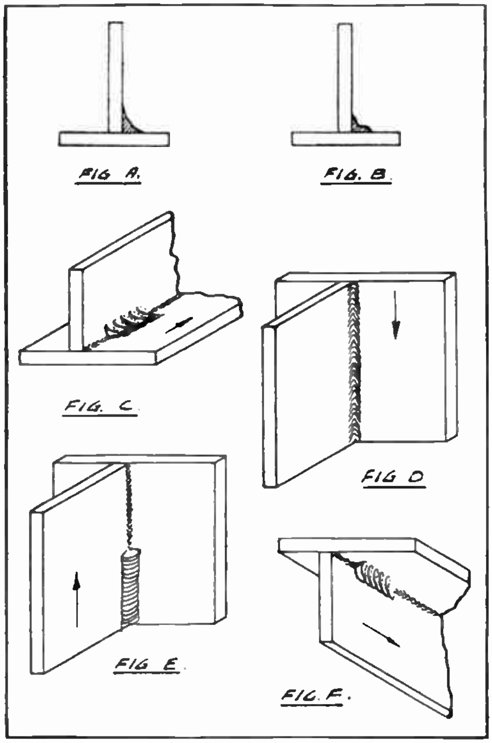
Also the manner of laying down the metal together with the correct inclination and movement of the electrode.

using a No. 8 gauge electrode and about 110 amperes.

First see that all traces of slag have been cleaned away and that the surfaces are clean and dry.

Start the bead at the top edge of the

required width of weld and move downward at an angle of about 45 degrees from the vertical in the direction of the weld until the opposite edge of the weld is reached; now sweep the arc upwards rather more quickly, parallel to the first bead, descend again over the upward run and repeat the cycle until the length of weld required is completed. In this way



ARRANGEMENT AND MANNER OF MAKING FILLET WELDS.

the electrode is kept moving over relatively cool plate, so that the deposit cools quicker than it otherwise would do if the electrode were allowed to stay in the same place long enough to deposit the complete section.

This method, if carefully carried out, ensures correct contour, facilitates separation of the slag from the weld metal, and permits, if desired, the section to be completed in one operation.

Sizes of Electrodes Required.

A fillet weld on a ⅜-in. lap can be built up to the full section with a sealing run and one finishing run with a No. 8 gauge electrode.

Heavier sections of fillet welds are made by adding successive runs applied in the manner already described for the second run of the ⅜ in. weld.

Faults Met With in Fillet Welds.

To turn out a strong neat-looking fillet weld with the same amount of deposited metal on each plate is by no means easy. The sharp wave-like motion of the electrode is necessary to keep the slag moving freely back over the deposited metal, otherwise slag inclusions may be found in the weld.

Again, in a fillet weld the slag has a relatively smaller area to cover than in any other type of weld, which means that there is proportionately more slag to contend with. Hence, it will be found advisable slightly to increase the current value as the section of plates to be welded increases or the power of the plates to conduct away the heat increases.

CONCLUSIONS.

We can sum up by emphasizing that the essential factors in producing good welding are:—

Keep a uniform short arc and make quite certain of effecting good penetration.

Fusing Metals Properly.

Not only is it necessary for the welder to make sure that the weld metal penetrates and fuses into the edges of the plates being welded, but special care should be taken that each successive layer of metal is well fused into the previous layer, thereby removing the possibility of slag or foreign inclusions in the deposited metal.

Cleanliness an Essential.

See that all joints or parts to be welded are thoroughly clean and free from grease, dust or other foreign matter; that the welding bench is clean and tidy, and that the welding tools and equipment are at all times in a state of good repair.

How an A.C. Motor is Made

THE COMPONENT PARTS BEFORE ASSEMBLY.

Here we see the complete set of parts used in the construction of a typical small A.C. motor. It will be seen that both stator and rotor are built up of laminations and that the stator is ventilated by means of holes behind the slots. The disc at each end of the stator is made of insulating material.

BY the courtesy of the Lancashire Dynamo and Crypto Ltd. we have been enabled to secure a most interesting series of photographs, which illustrate the whole process of building a fractional h.p. A.C. motor.

Details of two motors are shown here: A, a repulsion start induction motor, and B, a three-phase squirrel cage motor.

A.—Repulsion Start Induction Motor.

The repulsion start induction motor running on a 50-cycle supply gives a speed of approximately 1,490 r.p.m. light and 1,420 r.p.m. on its rated output.

The motor is switched direct on to the line by means of a double-pole switch without the use of a starting resistance.

This motor is fitted with a rotor wound in exactly the same way as a D.C. armature and fitted with a commutator. The brushgear is similar to that of a D.C. machine, but unlike a D.C. machine the brushes are shorted by a piece of flexible copper wire.

Operating Details of the Repulsion Start Motor.

With the brushes in the neutral position no starting torque is obtained and the rotor will not rotate. When the brushgear is moved to one side of the neutral the rotor will rotate in one direction, and if the brushgear is moved to the other side of the neutral position, the rotor will rotate in the other direction.

The position of maximum torque is obtained on test. The motor runs up to approximately two thirds of its synchronous speed as a repulsion motor; a centrifugal device on the commutator then operates, shorting all the segments of the commutator together and converting the rotor into a standard S.C. induction motor and it then has all the characteristics of an induction motor.

The starting torque of this class of motor is very good; 2 to 3 times full load with 2 to 3 times full load current.

A brush lifting device is fitted when perfectly silent running is required. This is a centrifugal device which raises the brushes off the commutator as soon as the latter is short circuited.

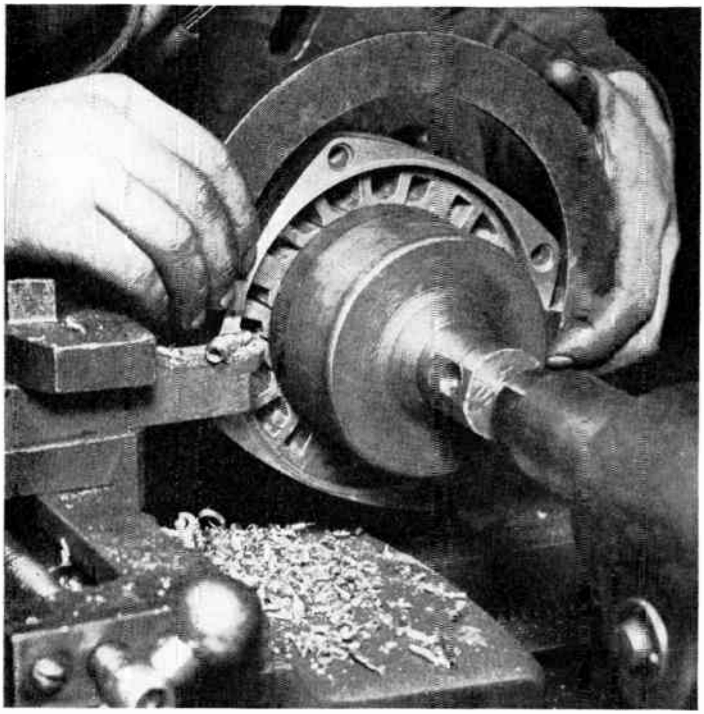
B.—Three-phase Squirrel Cage Motor.

The 3-phase type of motor has a S.C. rotor. Rods of copper are driven into the rotor and solid copper rings are brazed to the rods at each end as shown.

These motors start up with a triple-pole switch and are put direct on to the line. They start up against twice full load torque and will stand an overload of 100 per cent.

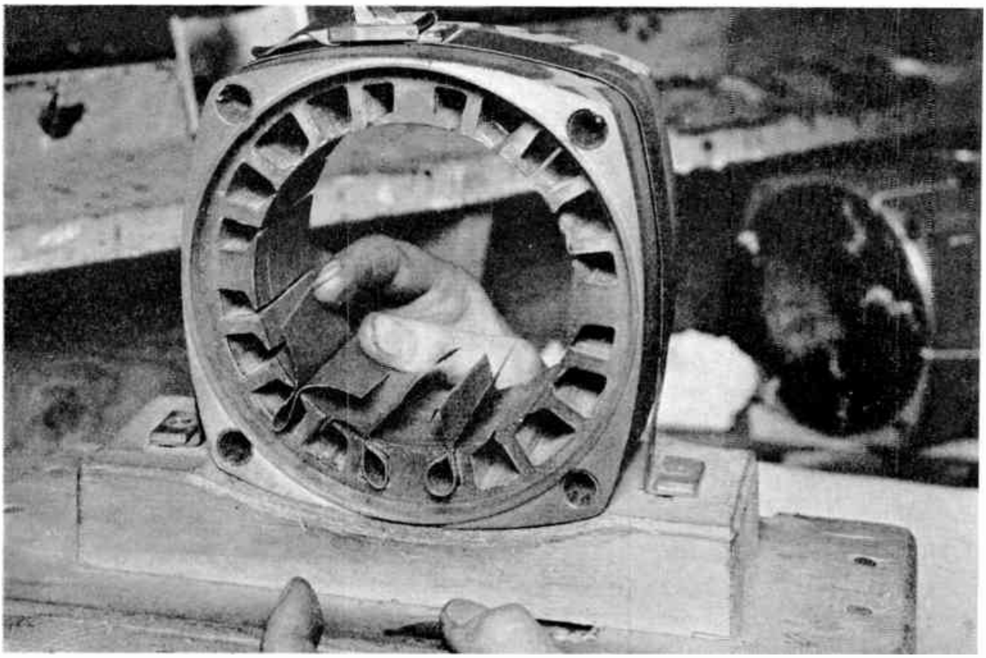
Assembling the Stator Stampings.

Note the studs at each corner which ensure that the slots of the complete stator are absolutely in line. The built up stator is put under a hydraulic press, and the clamping ring at each end riveted on.



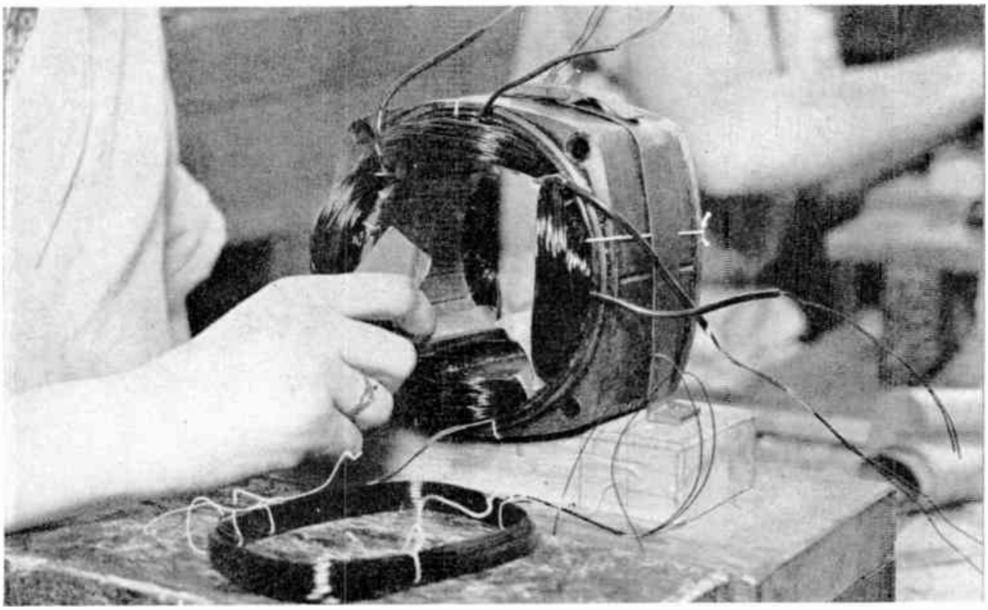
Turning the Register.

The built up stator is fitted on a mandril and a register turned on each side accurately to fit the endplates.



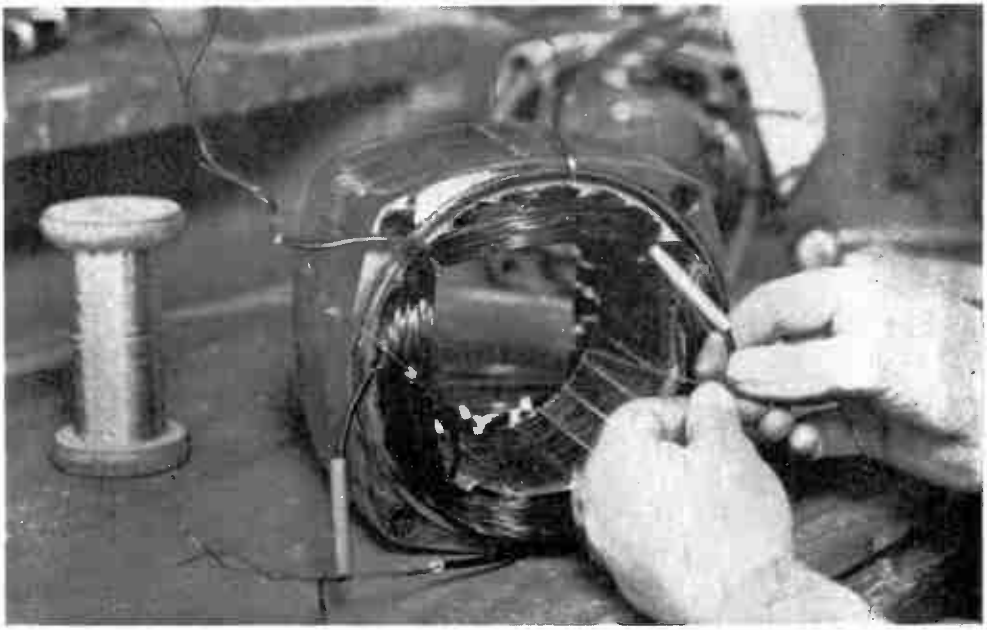
INSULATING THE STATOR SLOTS.

The insulation consists of a sheet of leatheroid and a sheet of empire cloth, both the same size and about ⅛ in. longer than the slot, and a second piece of thinner leatheroid which projects through the top of slot. The latter is used to prevent the insulation on the wire being damaged during winding.



INSERTING STATOR COILS IN POSITION.

The stator coils are former wound. The wires are fed through the openings of the slots, care being taken that the wires lie parallel and that there are no crosses.

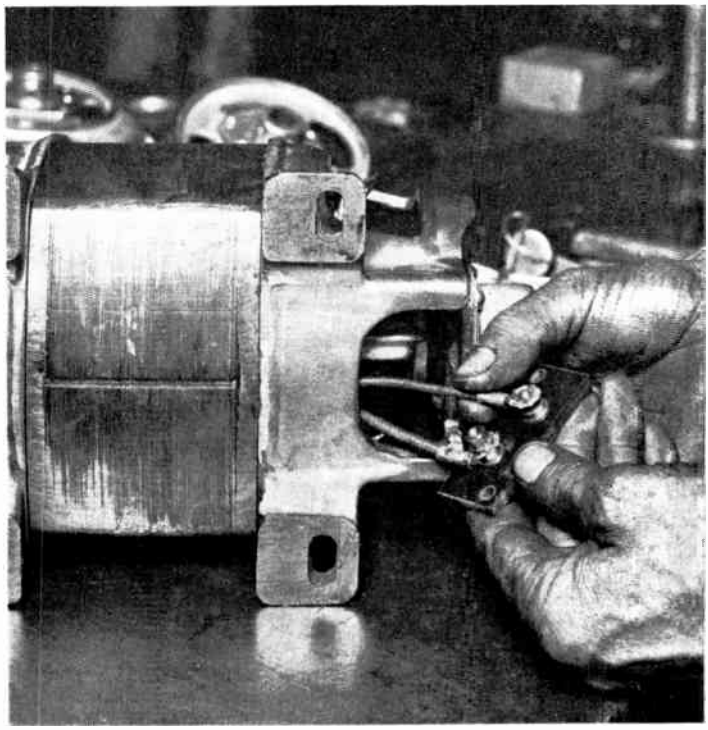


CONNECTING THE STATOR COILS

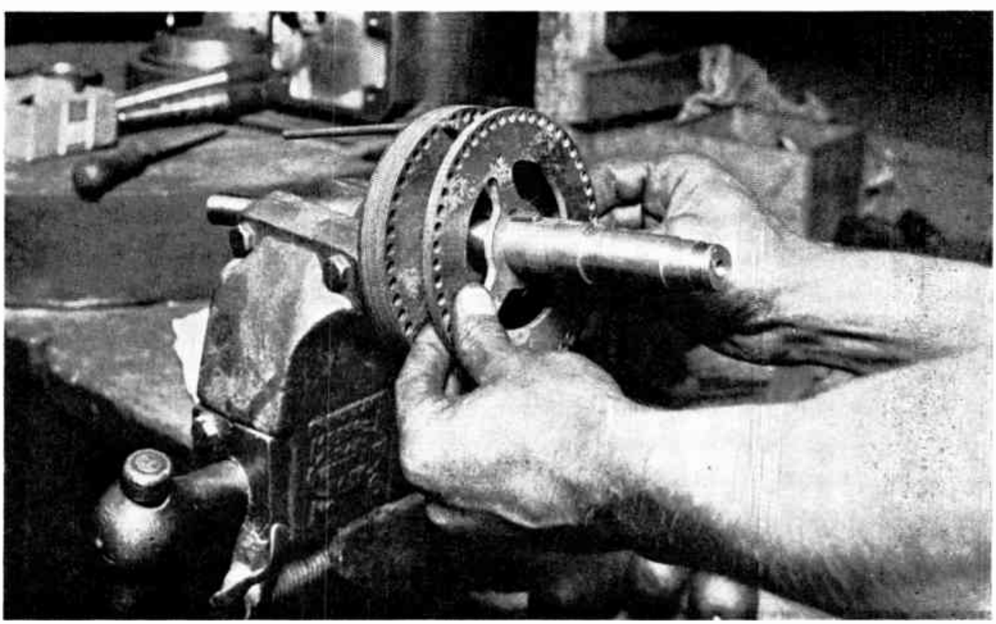
When all the stator coils have been wound, it is necessary to connect them to give the correct polarity. The ends of the coils are cut off to the correct length, cleaned and tinned. The starting end of one coil is connected to a terminal wire, the finish of that coil to the starting end of the next coil and so on. The finishing end of the last coil is joined to a terminal wire.

SPRAYING THE STATOR WINDING.

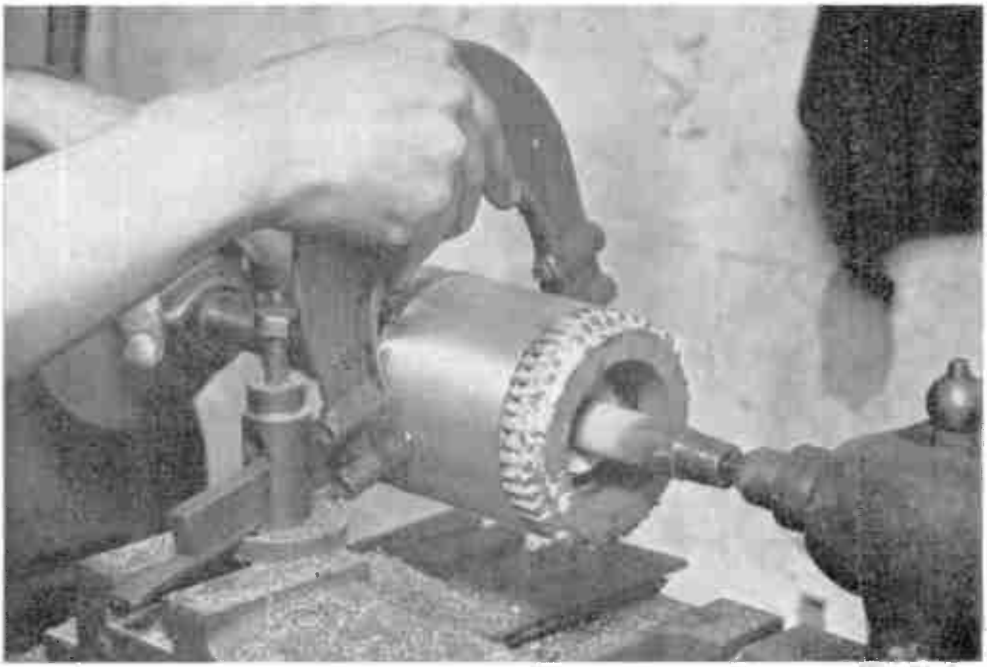
The completed stator is sprayed with an insulating varnish to make them impervious to damp.



CONNECTING STATOR COIL TO THE MAINS TERMINALS.
The two terminal leads are connected to terminals which are fixed in a bakelite terminal board.

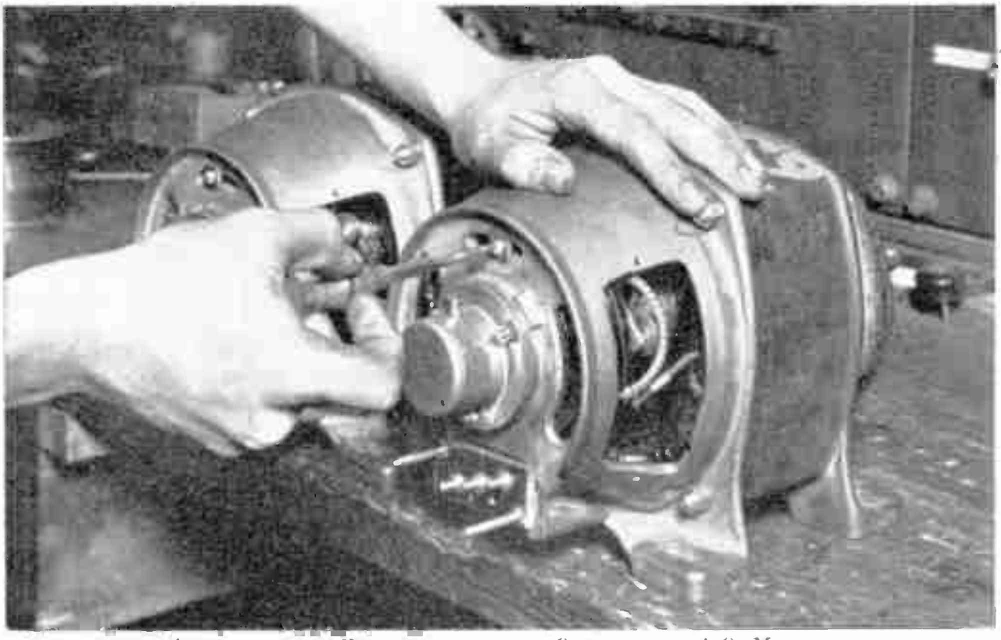


BUILDING UP THE ROTOR FOR THE SQUIRREL CAGE, THREE-PHASE MOTOR.
The rotor discs are threaded on a key on the shaft and the slots are kept in line by means of two rods on opposite sides.



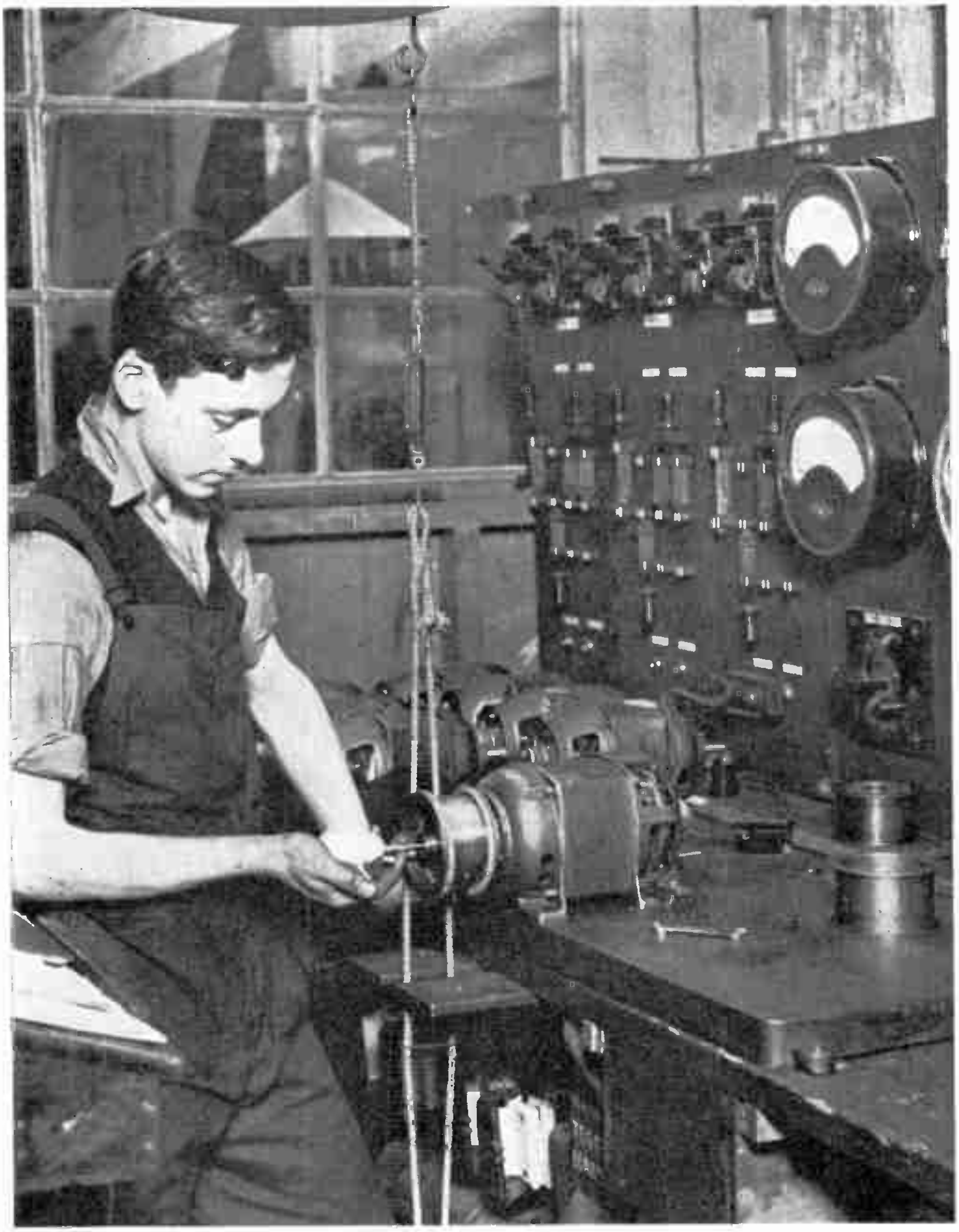
TURNING AND GAUGING THE ROTOR. (THREE PHASE).

The rotor, after building and winding, is turned so that its diameter is slightly smaller than that of the stator, the actual size depending on the size of the motor. This operation must be carefully performed as the clearance on these small machines is about 6 to 8 thousandths of an inch, and must not vary by more than 1 thousandth.



ADJUSTING THE BRUSHGEAR ON THE COMMUTATOR A.C. MOTOR.

This shows the assembled machine The position of the brushgear is adjusted by loosening the locking screw as shown, and moving the brush rocker in the slot to obtain the correct rotation and maximum starting torque.



FINISHED MACHINE ON TEST.

It is run on its normal voltage for about 2 hours to ensure that the bearings are satisfactory. It is then subjected to a brake test, and readings taken of current and watts input when running light, on its full rated output, and its maximum overload. The efficiency and P.F. are calculated and compared with that specified for this particular type of machine.

The starting and running up torque are also checked. The motor is then belted to a generator and run on its full load current for 6 hours. The temperature of the windings and iron are taken by thermometers to ensure that the motor does not overheat.

INTERPOLES AND ARMATURE REACTION

By H. E. J. BUTLER

Interpoles are used to secure sparkless commutation at all loads within the capacity of a D.C. dynamo or motor. This article emphasises why interpoles are necessary.

MOST modern D.C. dynamos and motors, except the very small sizes, have interpoles. The interpoles of a dynamo or motor are the smaller pole pieces located mid-way between each pair of main field magnet poles.

The Object of Interpoles.

The purpose of interpoles is to secure sparkless commutation at all loads within the capacity of the machine. To obtain efficient commutation on a machine without interpoles it is necessary to adjust the brush rocker when the load is altered.

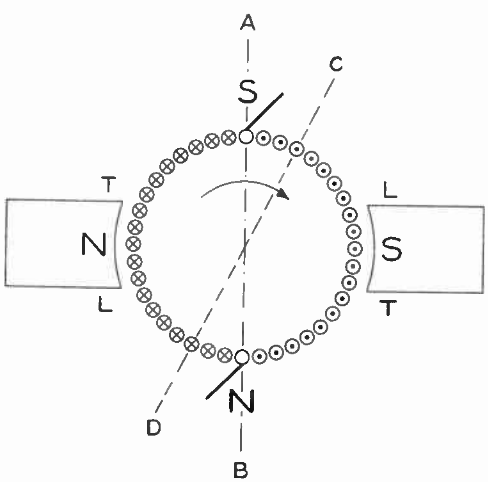
Interpoles must not be confused with compound field windings, which have a different object.

Armature Reaction.

The first illustration represents, diagrammatically, a plain bipolar dynamo without interpoles. The armature conductors are represented by a single ring of circular conductors between the two magnet poles. For the direction of rotation, shown in the diagram, the conductors facing the north pole are, as it were, going into the paper, and those facing the south pole are coming out.

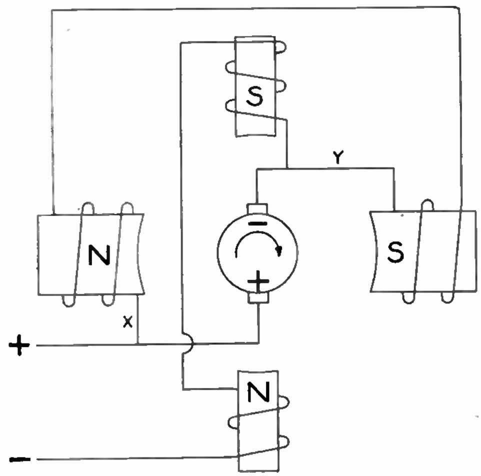
The field produced by the current in these armature conductors is similar in effect to a solenoid placed with its axis horizontal in the main field. The polarity of the armature field due to the current in its conductors is as shown. This effect is called armature reaction.

The direction of the lines of force due to the armature magnetization will be such that they flow out of the north armature pole into both magnet poles and out of both magnet poles, back to the south side of the armature, thus forming the complete magnetic circuit of the field due to the currents in the armature conductors. The lines flowing, or tending to flow, from the north magnet pole to the north armature pole are in opposition to one another, and the field due to the north magnet pole and the south armature pole are assisting, or strengthening, the main flux. Thus, the fields between A B the geometrical neutral axis and the leading pole tips L,L, are weakened. Conversely, the fields between the geometrical neutral axis and the trailing pole tips T,T, are strengthened. This is in effect as though the main field was moved round in the direction of rotation. That is to say, the magnetic neutral axis C D moved round in the direction of rotation.



THE THEORETICAL ARMATURE CURRENTS AND RESULTING ARMATURE REACTION EFFECT IN A BIPOLAR DYNAMO.

The direction of the currents in the conductors crossed is into the paper and the direction of the currents in those dotted is outwards. A B is the geometrical neutral axis of the main field and line C D represents the resulting neutral axis produced by the interaction between the armature and main fields.



THE CONNECTIONS OF A SHUNT CONNECTED BIPOLAR DYNAMO WITH INTERPOLES.

The Condition for Sparkless Commutation.

Since the brushes must bear on those commutator bars which are connected to the conductors passing through the region of the magnetic neutral axis, the brushes must, for a dynamo, be given a lead, corresponding in amount with the angular displacement of the main field. The armature currents are shown as though there were no field displacement, with the brushes set on the geometrical neutral axis. Under working conditions the brushes would be advanced by the amount of field displacement, represented by the angle between A B and C D.

It will be seen that, as the magnitude of the current in the armature conductors varies, due to variations in load conditions, the strength of the armature field will alter in sympathy. Consequently the angular advancement of the main field also varies, which explains the necessity for shifting the brushes with altered load condition.

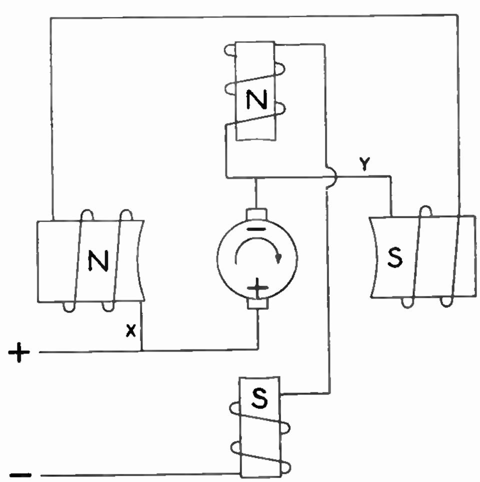
Neutralising Armature Reaction.

It is evident that in order to obtain the best running conditions at all loads with a fixed brush rocker, it is necessary to neutralise the effect of the armature reaction. This is accomplished by having auxiliary poles or interpoles. It will be seen that the armature south pole is at the top of the diagram, and the north at the bottom. If the interpoles are placed with their axes along A B and respectively of the same polarity and strength as those of the armature, the armature reaction is neutralised.

Since the armature field varies with the load, the strength of the interpole fields must vary in like amount. This is done in practice by exciting the interpoles by the main current, so that on no load when the armature reaction is nil, the interpole field is also nil, and when the load and armature reaction is a maximum the interpole fields are also at their greatest intensity.

Motor Armature Reaction.

The armature reaction in a motor is similar to that of a dynamo, but for the same conditions otherwise the polarity of the armature is opposite. If the first illustration were to represent a motor the polarity of the armature and the direction of the currents in the conductors would be reversed, for the same main field polarity and direction of rotation. Consequently, in a motor, the main field is distorted against the direction of rotation. The brushes of a motor without interpoles are therefore moved against the direction of rotation with increasing load.



THE CONNECTIONS OF A SHUNT CONNECTED MOTOR WITH INTERPOLES.

Rule for Interpoles.

The interpoles of a motor are of the same polarity as the adjacent main poles trailing them while the polarity of dynamo interpoles is the same as the adjacent main poles leading them in the direction of rotation.

Reversing Interpoled Machines.

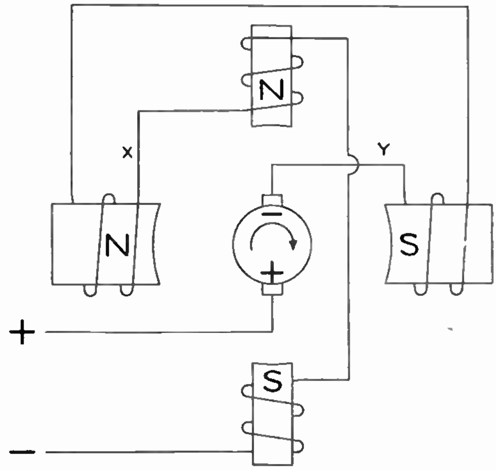
When the direction of rotation of a dynamo or motor with interpoles is reversed it is necessary also to reverse the relative polarity of the interpoles. Since the direction of rotation can be reversed by reversing either armature or main field, do not reverse by changing over the brush connections, because this leaves the interpoles unaltered. The best way is to change over the ends of the main field connections only, the interpole end connections being left unaltered.

Dynamo Interpole Connections.

The second diagram shows the connections of a bipolar shunt connected dynamo with interpoles. The direction of the windings on the main poles and interpoles is also shown. It will be seen that when the direction of rotation of the dynamo is reversed by transposing the main field leads X and Y, the polarity of the main fields is reversed, while the rule that the interpoles shall be of the same polarity as the adjacent main poles is still observed, because the polarity of the interpoles is unaltered.

Motor Interpoles.

The connections of the field poles and interpoles of a shunt wound motor are shown in the third figure. The difference between the polarity of the interpoles to those of a dynamo are shown by comparison with the previous figure. The direction of rotation of a motor of this type is accomplished by changing over the field leads X and Y. The connections of a series wound motor with interpoles is shown in the last illustration. As for the shunt motor the direction of rotation is best reversed by the transposition of the main field leads X and Y.



THE CONNECTIONS OF A SERIES CONNECTED MOTOR WITH INTERPOLES.

Multipolar Machines.

The principles explained may be applied to machines having any number of pairs of poles. The diagrams may be taken to represent only one pair of main poles and interpoles.

The term commutating pole is synonymous with the term interpole.

THE INSTITUTION OF ELECTRICAL ENGINEERS

PROGRAMME OF INFORMAL MEETINGS FOR SESSION 1932-1933.

At Savoy Place, Victoria Embankment, London, W.C.2.

(Hour of meeting, 7 p.m.)

1932.

Oct. 24. Discussion on "The Future Prospect for Electrical Engineers." (Opened by the President, Professor E. W. Marchant, D.Sc.)

Nov. 7. Discussion on "The Present Depression—Is Electricity the Way Out?" (Opened by Mr. J. F. Shipley.)

" 21. Discussion on "Loud-speakers." (Opened by Dr. N. W. McLachlan.)

Dec. 5. Discussion on "Street Traffic Signals." (Opened by Mr. E. S. Perrin.)

" 19. Discussion on "House Wiring Simplification and Elaboration." (Opened by Mr. F. Raphael.)

1933.

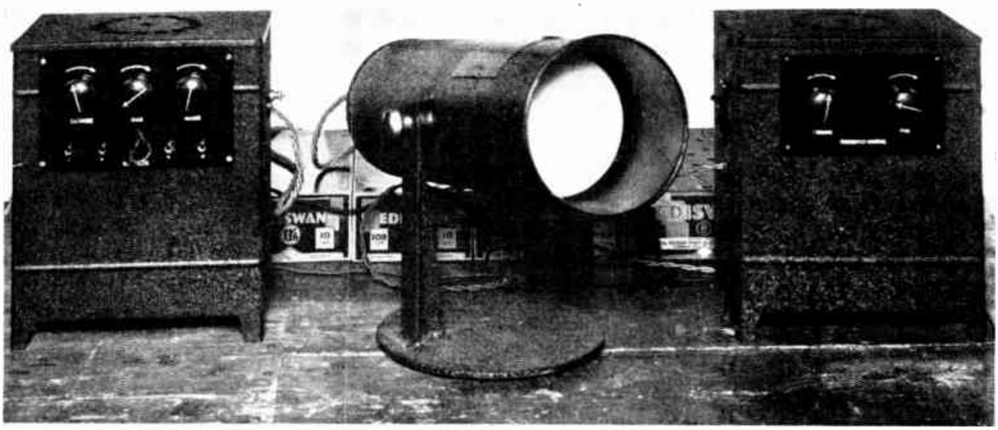
Jan. 9. Discussion on "Television." (Opened by Mr. H. J. Barton Chapple, B.Sc.(Eng.).)

" 23. Discussion on "The Use of Electricity in Agriculture." (Opened by Mr. F. E. Rowland.)

The Cathode Ray Oscillograph

By "Electrode"

The cathode ray oscillograph can be used for a great variety of purposes in electrical work. This article explains the principle of this useful device and describes some of the tubes now available on the British market



Complete Assembly of Ediswan Cathode Ray Oscillograph.
(This and the following photographs were specially staged to illustrate this article by the Edison Swan Electric Co., Ltd.)

It is now many years since Crookes gave the name of "cathode rays" to a certain effect which he observed to proceed from the cathode in an evacuated discharge tube. We now know that the effect was simply that of obtaining a beam of electrons, but the mysterious name "cathode ray" still persists, and the instrument in which the beam is turned to good practical account still goes under the name of "cathode-ray oscillograph," although there seems little doubt that we should now call it an "electron-beam oscillograph."

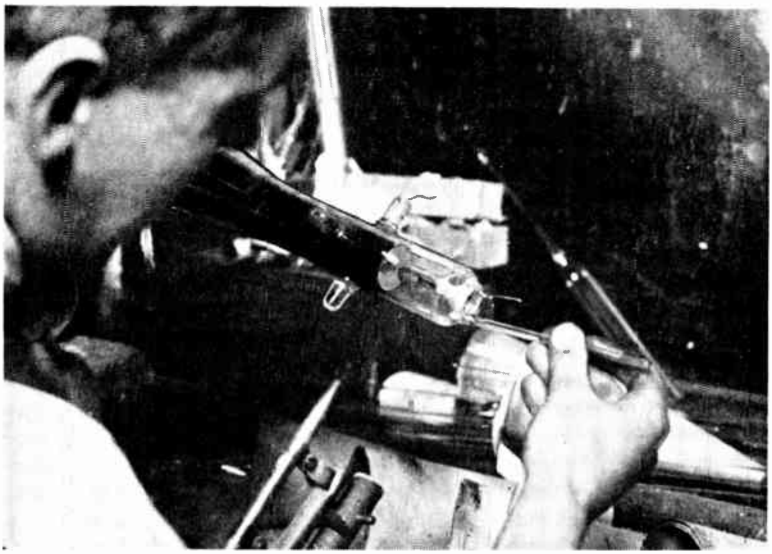
Instrument of Many Uses.

A very wide range of uses is claimed for the modern sealed-off glass type of oscillograph working at anode voltages of 300 to 400 to 1,500 or 2,000, and it is the purpose of this article to show how applicable it is to a great variety of electrical and allied measurements. Perhaps the best proof is to quote some of the uses to which it has already been applied. These include :—

Measurement and characteristics of machine noise.
Problems of phasing.
Synchronisation of alternators.
Standardisation and comparison of frequencies (high and low).
High-frequency voltmeter.
Measurement of amplifiers and performance of radio transmitters and receivers at high and low frequency.
Delineation of wave forms of transients, sounds, etc.
Measurement of nerve reactions.
Reception of radio signals.
Measurement of signal-strengths.
Visual radio direction-finding.
Accurate measurement of small time intervals.
Delineation of valve characteristics.
Properties of magnetic materials.
Mechanical problems where mechanical impulses or forces can be converted into electrical effects.
Television.

The last-named application may well prove to be the widest of the many uses.

L



STAGES IN THE MANUFACTURE OF A CATHODE RAY TUBE.
Sealing an exhaust tube.

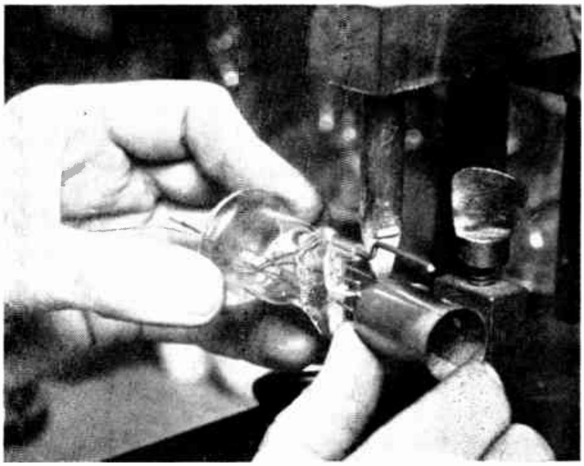
filament is heated by current (usually of about 1 ampere or so) to a medium red, when it becomes an emissive source of electrons. The anode is a disc with a central hole. If a steady voltage of, say, 300 to 500 v. is applied between anode and cathode, as shown, electrons emitted from the cathode are drawn from the filament towards the anode. Some of the electrons arrive in the vicinity of the anode with sufficient velocity to shoot through the central hole. By various means it can, indeed, be arranged that by far the greater number of electrons leaving the cathode are shot through the hole instead of being taken directly into the metal of the anode.

It is true that up to date it has not been much used in England, but considerable progress has been made in America and in Germany. At the recent Berlin Wireless Exhibition at least two television receivers were shown using cathode-ray oscillographs for domestic reception. This may well be taken as an indication of the simplicity of their use.

Production of Electron Beam.

The general principles of the cathode-ray tube are really very simple, although it should be said that a great deal of work has been put into the process of applying these principles and getting them into their present amenable condition of use. These principles are illustrated on page 131. The containing envelope is a glass bulb of the shape shown and seen more clearly, perhaps, in some of the photographs of actual commercial tubes.

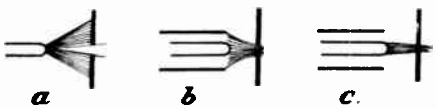
The cathode is a filament usually of the typical loop shape approximately as shown. The



STAGES IN THE MANUFACTURE OF A CATHODE RAY TUBE.
Showing the electrodes being welded in position.

How the Electrons are Kept in a Concentrated Beam.

After they have shot through the anode there is a natural tendency for them, as it were, to repent and try to get back into the metal of the anode, after the usual manner of the diode or two-electrode valve. By still other means, however, it is possible to keep them in a concentrated beam, which is of fine cross-section at the point where it hits the inside of the bulbous end of the tube. This end is coated internally with a material which has the property of glowing when it is struck by the electrons, so that



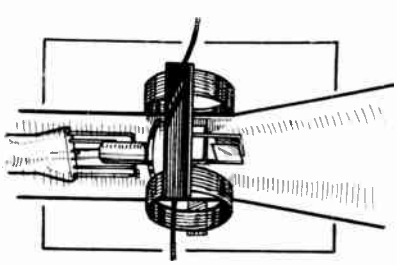
Showing the Use of a Negative Cylinder Round the Cathode to Concentrate the Beam Through the Anode.

(*a*) Shows no cylinder; (*b*) a cylinder with insufficient negative bias, and (*c*) a cylinder with correct negative bias.

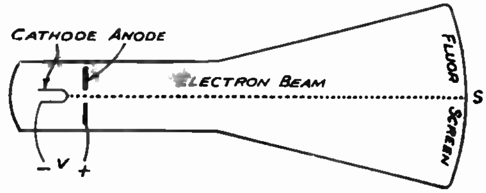
the point S glows with a fluorescence, the brightness of which depends upon the value of the "accelerating voltage" V and whose colour depends on the nature of the material.

Focusing the Beam.

The methods which are used to maintain or, rather, to control the beam so that it arrives in the form of a fine point are interesting, and, although they do not actively concern the user, they are worth a brief mention. In the first type of cathode-ray oscillograph that was commercially available some nine or ten years

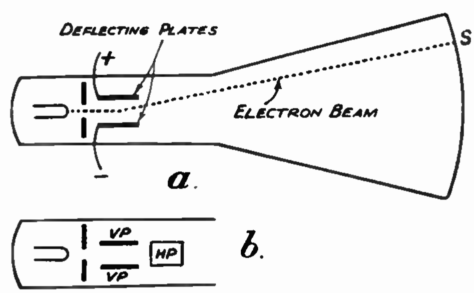


Deflections of Beam by Magnetic Field Due to Current-Carrying Coils.



Principles of Producing Electron Beam in a Cathode Ray Oscillograph.

ago—that of the Western Electric Co., later Standard Telephones and Cables Co. —the beam was "focused" by means of ionisation of the small residue of gas (argon) that remained in the tube. The anode was in the form of a short fine tube which first helped to project the electrons in a beam. In their progress along the tube the electrons collided with atoms of the low-pressure gas and produced positively charged ions which tended to move towards the cathode in the opposite direction to the electron movement. In doing so they created a magnetic field



Principle of Deflecting Electron Beam by means of Plates Within the Tube.

which constrained the electrons in a narrow path.

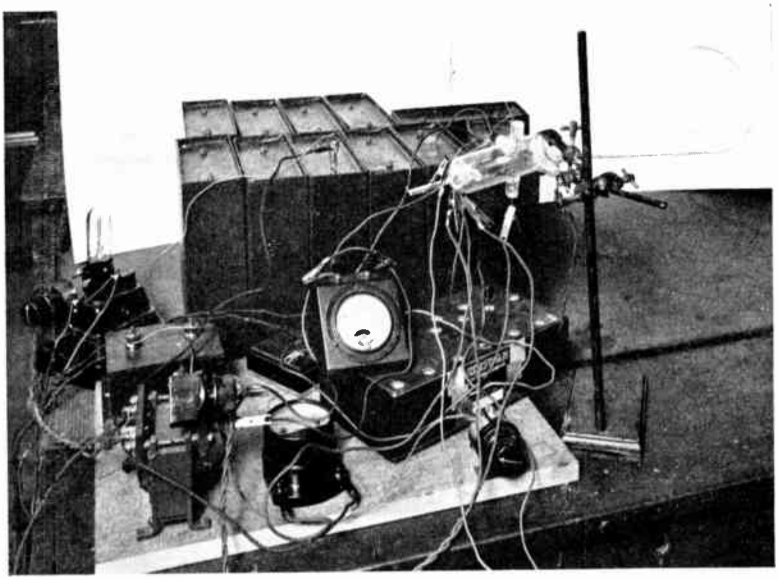
In the process of design and manufacture the dimensions of the bulb and the pressure of the remaining gas were adjusted so that, at the normal working temperature of the filament, the degree of ionisation produced was such as to give exactly the magnetic field required to focus the beam at the fluorescent screen. The degree of ionisation was, in turn, controlled by the filament temperature, which was thus the sole control.

Concentration by Cylinder Round the Cathode.

More recently it has become the practice to surround the filament by a metal cylinder, an innovation which was due to the German, M. von Ardenne. This cylinder is made negative to the filament and immediately exercises an all-round constraint on the (negative) electrons shooting off from the filament and gets them into the form of a convergent beam, which is all the more easily shot through the anode aperture. An illustration of this process is shown in the sketch on page 131, which is traced from photographs made by von Ardenne.

In (a) no cylinder surrounds the filament, in (b) the filament is surrounded by a cylinder which is not, however, sufficiently negatively biased and therefore leaves the beam still coarse in passing through the anode. In (c) the cylinder is adjusted to the correct negative voltage and causes a sharp beam to pass through the anode aperture. Once through the anode, the electrons are kept in a fine beam and brought to focus by ionisation after the manner already considered.

There are thus two controls involved in focusing the beam, one the filament temperature and the other the cylinder biasing voltage. In practice, however, this dual control offers no real difficulty, and the use of the shielding cylinder has had a valuable effect in permitting the use of much higher voltages, while also adding to the life of the filament. The whole of the beam-producing system is frequently referred to as the "electron gun."



Testing an Experimental Cathode Ray Tube.
Showing how the apparatus is rigged up in the laboratory.

USING THE BEAM.

The foregoing account deals entirely with the process of obtaining the electron beam and getting it to shoot along the axis of the tube. What are we to do with it once we have it? In the third sketch on page 131, we have the same elementary beam-producing system as previously shown. Additionally, however, two parallel metal plates are introduced into the tube a small way along the beam from where it emerges from the anode. It must be remembered that the electrons forming the beam are each small *negative charges*.

Applying a D.C. Voltage.

If, therefore, we apply to the parallel plates a voltage of the sense shown, the upper plate, positively charged, will attract the electrons, while the lower plate, negatively charged, will repel them. The beam between the plates is thus deflected upwards, and the fluorescent spot S is moved to a new steady position, as illustrated.

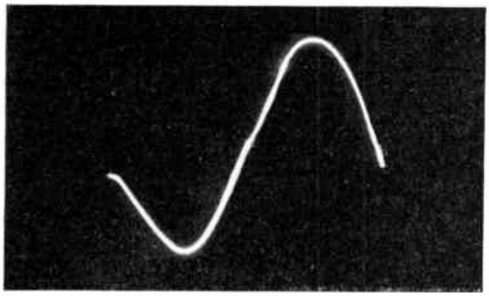
Actually it will be seen that on account of the length of the beam there is a considerable leverage applied to the deflection of the beam, so that a small movement in the neighbourhood of the deflecting plates gives a much bigger movement to the spot on the screen.

Effect of Reversing the Voltage.

If the voltage on the deflecting plates be reversed it will be seen that the spot would similarly be moved *downwards*.

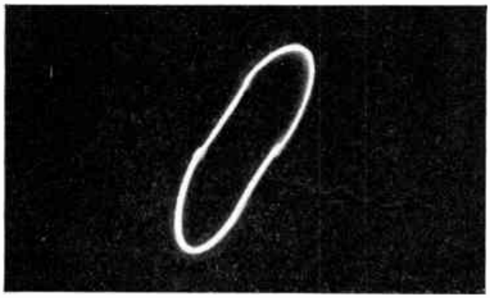
Applying an Alternating Voltage.

If, instead of the steady D.C. voltage,

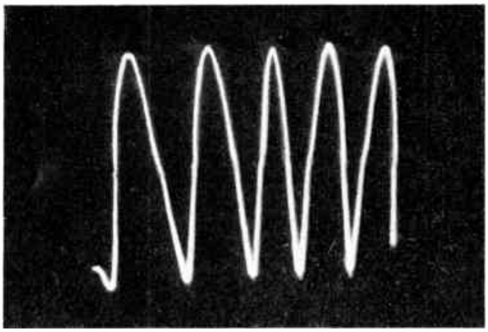


WAVE FORM ON LINEAR TIME BASE.

we apply an alternating voltage to the deflecting plates, it will be seen that the fluorescent spot will move up and down on the screen in accordance with the alternating frequency. If the frequency is low, e.g., below about 20 per second or so, the eye will be able to detect the fact that the spot is vibrating up and down. If the frequency is high, say, 50 ∽ or more,



ELLIPSE FORMED BY DIFFERENCE OF PHASE BETWEEN DEFLECTOR POTENTIALS.

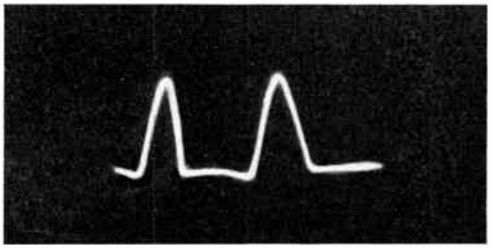


TRAIN OF WAVES SHOWN BY LINEAR TIME BASE.

the spot will still vibrate up and down on the screen, but its rate of vibration will be so rapid that the eye will not be able to follow its individual excursions and will simply see an apparently steady vertical line on the fluorescent screen.

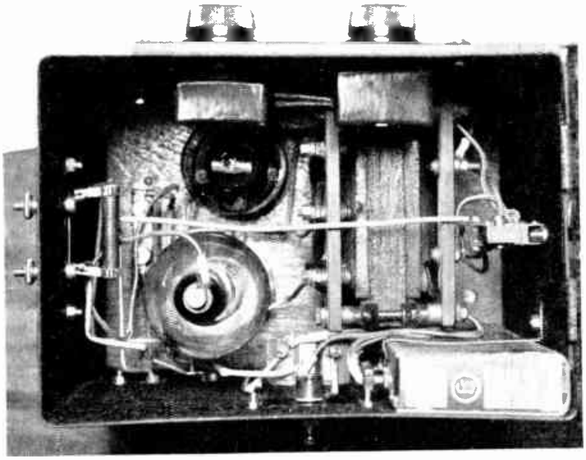
How the Beam Serves as an Indicating Device.

The essential use of the electron beam is thus to serve as an indicating device,



WAVE FORM OF ½-WAVE RECTIFIER OUTPUT.

but it is an indicating device which is incomparably light compared with any other that can be devised. Being merely of electrons, it is effectively free of inertia and can thus be vibrated at practically any frequency. Thus the same electrode system shown in the third sketch can be used for deflections of mains frequencies of 25 to 50 ∽ or it can equally be used at hundreds of kilocycles. A further advantage is to be found in the fact that the electron beam behaves like a sort of universal joint and can be deflected in any direction.



INTERIOR OF TIME BASE UNIT.
Showing mercury vapour discharge tube; bias battery for adjustment of time-base length; and diode used as frequency controller.

Thus if another pair of deflecting plates be introduced at right angles to those already shown, they can be used to deflect the beam horizontally.

For example, in this sketch (b) the plates VP are those already shown in (a) deflecting the spot vertically as considered above; H P is one of a pair of plates at right angles capable of deflecting the spot horizontally. Practically all the applications of the oscillograph already cited involve the use of both deflecting systems.

DEFLECTION BY CURRENT-CARRYING COIL.

Besides being capable of deflection in the manner considered, it is also to be remembered that the electron beam is a *stream of moving electrons.* This is exactly the equivalent of a current, so that the beam is effectively a current-carrying wire, with the important difference that it is a wire of no inertia. As a current-carrying wire, however, the beam is capable of being deflected by a magnetic field. This is easily shown by bringing a magnet close up to the tube, when the beam is seen to move to a new position. Instead of using the plates for deflection, we can therefore deflect the beam either steadily or in an alternating manner by means of the magnetic field from current-carrying coils brought close to it.

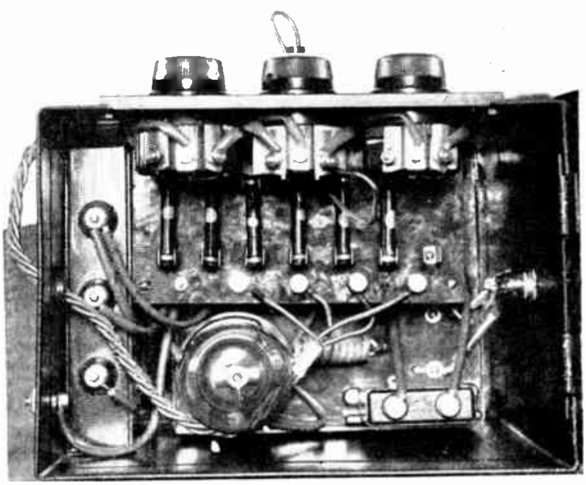
A sketch shows the neck of a tube with a pair of such coils attached to it, the two coils being, of course, in series and arranged to be additive in their effect on the beam. Another pair of coils could also be used at right angles to those shown so as to give two-dimensional deflections, as with the plates. It is indeed possible to combine deflection by plate and by coil, and some applications do use both means of controlling the movement of the beam.

An Important Point to Remember.

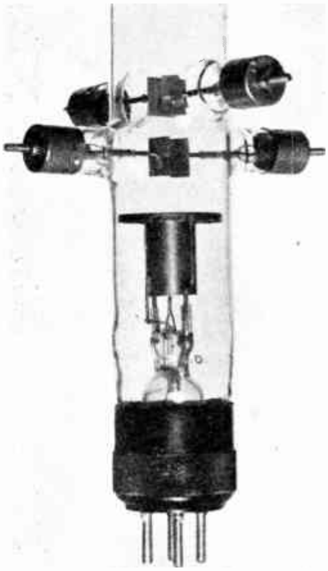
An important point in using either system, however, is to remember that in the case of deflection by the plates the movement of the spot is at right angles to the plane of the plates, while in the case of coils the movement is parallel to the plane of the coils.

DEFLECTIONAL SENSITIVITY.

Another point of interest that should be mentioned here is the sensitivity of the electron beam to deflecting forces. Using electrostatic deflection by means of the plates, the sensitivity of deflection



INTERIOR OF EXCITER UNIT.



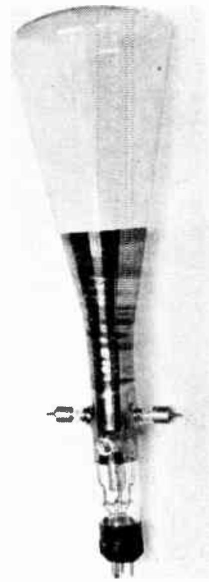
Showing the Electrode System and Deflector Plates in an Ediswan Cathode Ray Tube.

varies inversely as the accelerating voltage (V of first sketch). Thus with anode voltages of 300 a tube may give a spot movement of 1 mm. for one volt on the deflecting plates. If the beam be accelerated by 1,000 volts, so as to give a much brighter spot, 3.3 volts will be required to give the same deflection as before, etc. With magnetic deflection by means of coils, the sensitivity is inversely proportional to *the square root* of the accelerating voltage. Thus if a certain pair of coils gives 1 mm. deflection for one milliampere with an anode voltage of 300, 1.82 milliampere will be required if the accelerating voltage is increased to 1,000.

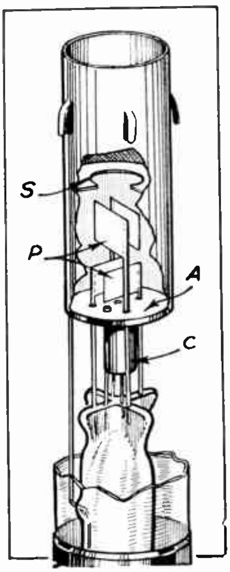
FLUORESCENT SCREEN MATERIALS.

A number of materials have the property of glowing under the influence of bombardment by the electron beam. One favourite material is zinc silicate or Willemite, which glows a bright yellow-green and has the merit of giving a good response at relatively low accelerating voltages. Another material is calcium tungstate, which glows a pale blue. It requires a much higher voltage for equal visual brightness—as compared with zinc silicate — but its colour is more photographically active.

Thus for maximum sensitivity and visual observation zinc silicate is the better material, while for photographic purposes, calcium tungstate is more advantageous, although it is accompanied by some loss of sensitivity to deflection. Mixtures of these materials have been used to provide a screen which gives a compromise of these qualities. With modern tubes, good photographic response for many rapid types of recording can be obtained with accelerating voltages of 1,000 or 1,200, using a screen of calcium tungstate.



Complete Ediswan Cathode Ray Tube.



Electrode System of Cossor Oscillograph.
C is the controlling cylinder with the filament within it. A is the anode; P the deflecting plates; and S an electrostatic shielding screen.

BRITISH COMMERCIAL OSCILLOGRAPHS.

The first available tube was, as has already been stated, that of Standard Telephones and Cables. On its original appearance, about 10 years ago, this instrument marked a very notable advance in raising the oscillograph from the level of a laboratory toy to that of a working tool. An example of its utility is to be found in the fact that it was very quickly used to show—for the first time—the shape of wireless atmospherics, revealing that these are transients having an average duration of the order of one-thousandth of a second. This is surely an adequate tribute to the utility of the device. The Standard Co.'s oscillograph was suitable for working at voltages of only 300 or 400.

After a period of little development in tube design, the next notable step was that due to von Ardenne, viz., of introducing a controlling cylinder round the filament. Besides improving focusing, this permitted operation at much higher voltages, i.e., up to 2,000 or 3,000, with consequent increase of the uses to which it could be applied.

The Ediswan Oscillograph.

A British tube of appearance and construction generally similar to that of von Ardenne is that of the Ediswan Co. The upper tube has only one pair of deflecting plates, but the lower has two. The general dispositions of cathode, cylinder and anode are approximately on the lines shown in the fourth sketch. The connections to filament, cylinder and anode are made by a valve socket of ordinary British pattern; connection to the deflecting plates is made by side stalks on the tube. The Ediswan tube can be worked up to 2,000 volts.

All the photographs of apparatus as well as the oscillographs shown in page 133 were specially taken to illustrate this article. For the facilities in staging and operating the apparatus we are indebted to the Ediswan Electric Co., Ltd.

A Recent Design.

More recently the Standard Telephone Co. has produced a new design, which also uses a cylindrical shield, but working at a slight positive voltage. The anode is very close to the filament and cylinder, being separated by mica insulation. Connection to all electrodes is made by a socket of American valve type. This oscillograph is still of the low voltage type, being intended for operation at 300 to 600 volts.

The Cossor Oscillograph.

The latest comer to the British market is that of Messrs. A. C. Cossor, the valve makers. This is an extremely well-designed oscillograph, capable of being used from 300 or 400 volts up to 2,000 volts or so. All eight connection points—two for filament, one for cylinder, one for anode and four for deflecting plates, are brought in special pinches on to an eight-point cap, fitting with bayonet catches into the special low-capacity socket as shown. The anode is spaced from the cylinder and filament by means of mica, capable of high-voltage operation of the order stated.

The Shielding Cylindrical Screen.

An excellent feature is the addition of the shielding cylindrical screen S of the sketch on page 135. This is connected to the anode, and serves to prevent the formation of static charges on the walls of the oscillograph. The Cossor tube is available with visual or photographic screen materials, and samples which the writer has seen in operation suggested that they gave an excellent response at the various operating voltages appropriate to their purpose.

Operating Voltages.

It is impossible in the course of this single article to cover all the practical points that arise in connection with the cathode-ray oscillograph. It is hoped, however, to give further data later. Before concluding the present article, however, it may be mentioned that, although operating voltages of 1,000 or more have been quoted, these need represent little difficulty in practice. The currents taken are very small, being less than half a milliampere at even 1,000 or 2,000 volts. If A.C. supply is available, the high voltage can be obtained from a simple type of rectifier unit, the small currents involved making smoothing very easy and inexpensive.

The Installation of Underground Cables

By C. Cameron Kirby, A.M.I.C.E., A.M.I.E.E.

In this article Mr. C. Cameron Kirby describes the three most modern methods of installing cables underground, i.e., the solid system, the conduit system and the direct system

THE general principles involved in laying cables apply equally to all types of cables, irrespective of the electrical pressure for which they are intended. Cables may be single core, twin, three core, four core or may possess additional cores for the purpose of a street lighting switch wire. They may incorporate small section pilot wires for use with protective gear or private telephone systems for communication between substations and the central works' offices. In the case of super tension cables of 33,000 volts working pressure or higher, greater care in handling and more gentle treatment in bending the cable round corners is called for than in the case of low tension cables, but in other respects the problems are similar.

Modern methods of installing cables underground may be divided into three sections: (A) solid system, (B) conduit system, and (C) direct system.

Feeding a .5—.25—.5 sq. in. Low Tension Three-core Armoured Lead-covered Cable in Trench.

LAYING CABLES SOLID—SYSTEM (A).

In this case the cable may be plain lead covered with no additional protection over the lead sheath or it may be armoured. Troughs are laid in the bottom of the excavated trench and cable placed in position in the trough. Bitumen is poured into the trough and the troughing covered with bricks or tiles or other suitable protection. Various types of troughing have been used in this method.

Types of Troughing.

Creosoted wood has been extensively employed on many undertakings and has many advantages. The resistance it offers to damage from stray pickaxes and bars is considerable. It can be obtained in long lengths and is reasonably cheap and may be installed with comparatively unskilled labour. Cast iron troughs make a sound job for footpath work. can only be obtained in short lengths and are expensive. Stone-

THE CABLE TRENCH BEFORE FILLING IN.

ware troughs have been extensively employed, but here also the lengths are limited to about three feet, and the frequency of joints in the troughing is a source of weakness. Where cables have to cross a road carrying heavy traffic, both iron and stoneware troughing have been found to give rather unsatisfactory service as the pounding of heavy vehicles in time results in the troughing collapsing at the joints and failure of the cable ultimately results. Road crossings should never be laid at a depth less than three feet, and greater depth is always advisable with both systems (A) and (B).

How the Cables Are Installed.

In installing cables on the solid system, troughs are first laid and bedded on sifted earth at the bottom of the trench. The troughs are jointed for as many yards as it is intended to "pitch in" in one operation. For an individual cable the internal dimensions of the troughing might be 5 in. wide by 4 in. deep. Saddles are then placed on the bottom of the trough from 1 ft. to 2 ft. 6 in. apart, the more flexible the cable the nearer they are placed. Wood bridges or saddles should not be used as these absorb moisture through joints in the troughing and provide leakage paths for stray currents to leave the sheaths of lead covered cables.

Best Material for Saddles.

The best material for the saddles is asphalte which as well as being non-hygroscopic, softens on the surface in contact with the hot compound and tends to unite with this compound into a homogeneous filling. The cable is now run off the drum and laid alongside the troughing in the bottom of the trench. Any loose soil that may have fallen into the troughing is brushed out, the cable is placed in position on the saddles, and very hot compound is poured in to a depth of about ½ in. After this has been allowed to cool off somewhat, the troughing is filled up with compound at a temperature of from 250° F. to 300° F.

The Final Stage.

The final stage is to "top up" and place the covers on the molten compound, thus effectively sealing the troughing. In the case of wood troughing the covers will normally be creosoted wood planks about 6 ft. in length. Where sections of the troughing terminate in brick pits, as is frequently the case when disconnecting boxes are inserted in circuit, the troughing should be finished off with asphalte. This prevents the bitumen from running into the pit, and effectively seals the troughs should any heating of the cable occur. Mains laid on the solid system should be installed in fine weather, as the effect of showers on partially completed work is very harmful.

Advantages of the Solid System.

This system of laying is invaluable in those areas where stray currents from tramway rails are known to exist and is probably the best solution to the problem of electrolysis of underground cables. It is also the best method where cables have to be laid in "made" ground, consisting of clinker or chemically active ground. When carefully installed it is a safeguard against chemical or electrolytic corrosion. The cables cannot, however, carry as much current without undue heating when installed in this manner as with system (C). It possesses similar limitations to this system inasmuch as the cables have to be of sufficient size when originally installed to allow for future development in the load.

CABLES IN CONDUITS—SYSTEM (B).

The conduit system consists of ducts or pipes laid under the footpath or roads into which are drawn lead covered cables. These pipes are laid so as to drain into pits or draw boxes every 200 to 300 ft., and the pits have sumps at the bottom which are usually connected to the surface water draining system of the local authority. These pits should be sufficiently large and deep for a jointer to work in comfort. This size will vary with the number and type of cables installed, but should not be less than about 4 ft. 6 in. by 3 ft. wide by 3 ft. deep.

Where possible the cables should be brought out of the duct mouth at one end of the pit, round the side of the pit, and fastened to the wall by cable hangers or brackets, and then into the ducts at the other end of the pit. This obviates the cables being used as steps to assist a man to descend to the bottom, and reduces maintenance to a considerable extent, especially with the smaller size of cables. Pits are normally fitted with double frames and covers, these being made especially strong for roadway use, and they are lifted by means of special keys inserted in holes at each side of the covers.

Materials Used in Conduit Systems.

The materials used for conduit lines may be cast iron, fibre, or glazed stoneware pipes, the latter being more generally used than other types. Cast iron pipes are very suitable in those areas liable to electrolysis, and they can be manufactured in long lengths with spigot and socket joints. The joints are made with yarn and lead and then caulked. Cast iron pipes are fairly expensive but are often

View Along Cable Trench.
Showing tunnel under entrance to works.

used for cables crossing bridges, where the amount of working depth is very limited. Fibre conduits are made in 5 ft. lengths, and are impregnated with a compound of bitumen during manufacture. The jointing is of the spigot and socket type and the overall diameter of the joint is the same as the pipe. Only single pipes are made of this material.

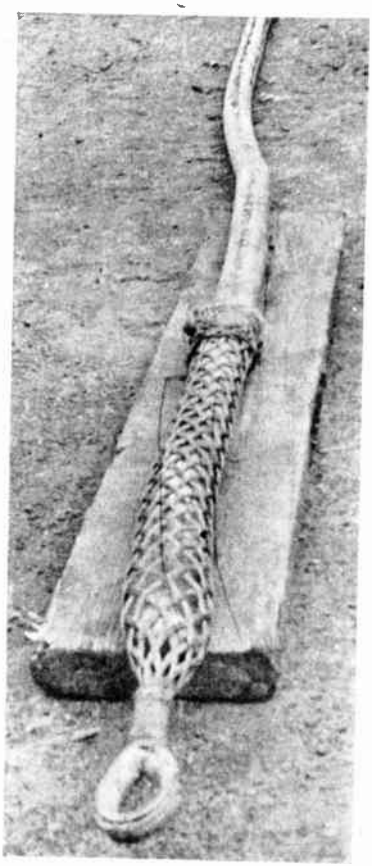
Installing Fibre Conduits.

When installing these pipes the trench is excavated to the required depth and width. A concrete bed is laid on the bottom of the trench to form the base for the number of duct ways required. This bed will usually be from 4 in. to 6 in. thick, varying with the nature of the ground and the weight of the traffic above. The first tier of pipes is then laid on the concrete bed, and these are evenly spaced by means of a wooden comb-like template designed to take the requisite number of pipes on each tier.

Lining Up the Templates.

These templates are placed about 3 ft. apart along the pipe line and are lined up and kept in position by means of packing from the side of the trench. The spaces between these templates are now filled in with a mixture of cement, sand and fine spar or foundry slag, and the sides of the trench are filled in with rough concrete to the level of the pipes. The templates are next removed and the spaces which they have left are filled in with the fine concrete mixture. The first tier is allowed to set for several hours, after which the process is repeated until the total number of duct ways is laid, and finally a rough concrete is again used to complete the block. It is advisable that the concreting of the ducts between two pits should be completed as quickly as possible, to ensure the keying together of the concrete.

One of the advantages of fibre conduits is that the pipes can be slightly bent, if desired, by warming them with a blow lamp, and this enables one to avoid obstacles.



CABLE GRIP ATTACHED TO END OF PLAIN LEAD-COVERED CABLE.

How Stoneware Ducts are Installed.

Stoneware ducts may be either of the spigot and socket type or butt jointed type and are manufactured in varying lengths up to 3 ft. and from single pipes to sections of 9-way conduits. The spigot and socket type are usually manufactured with self-aligning joints, and both ends have a layer of bituminous jointing compound attached to them during manufacture. It has been claimed that no additional treatment is necessary in order to make a waterproof joint. It is, however, an advantage to paint the joint surfaces at each end of the pipe with a hot mixture of one part of Russian tallow to four parts of resin, melted together. It is essential to apply the mixture hot and not in a thick state, the correct consistency being that of a heavy motor oil.

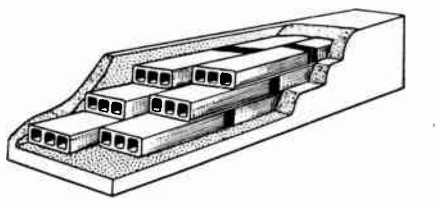
The Butt Joint.

With the butt joint the conduits are aligned by means of wooden mandrils. A band of prepared canvas is wound round the joint to prevent loose material getting into the duct line during the completion of the work. An iron shoe or mould is next placed in position round the joint and a strong cement mixture run in to this. With both these types of conduit, the joints of adjacent pipes are staggered. In the case of a multi-way conduit of the butt-jointed type installed in the carriageway, it is sometimes deemed advisable to encase all the pipes completely in concrete. This is shown in the sketch which also depicts the staggering of the joints.

When layers of multi-way spigot and socket ducts are placed on top of each other the spaces between the layers are filled with cement mortar to a thickness of about 1 in. The ducts are thus supported over the whole of their area, and no undue weight is thrown on to the socket end. In cases where the ducts are laid on earth, the earth should be scooped out at these points where the collars of the socket end will come, and this will ensure a level bedding of the duct line.

How the Cable is Pulled into the Duct.

Before pulling a cable into a duct, the latter has to be "rodded up." Drain rods about 5 ft. in length are pushed into the duct and fastened to each other by means of a screw coupling and locking catch. When the whole length of the duct line between the two adjacent pits has been rodded up, a light rope is attached to the last rod. This is pulled in, and an attachment to it is also pulled through the duct. This attachment consists of a mandril, about ½ in. less in diameter than the duct itself, and if this passes without difficulty the charge hand knows that the duct is clear. To the other end of the mandril a stouter rope, sometimes of steel, is tied and this rope is used to do the actual pulling in of the cables. This rope may be attached to a cable grip made of fine steel wires which goes over the lead sheath of



How the Stoneware Troughs are Arranged

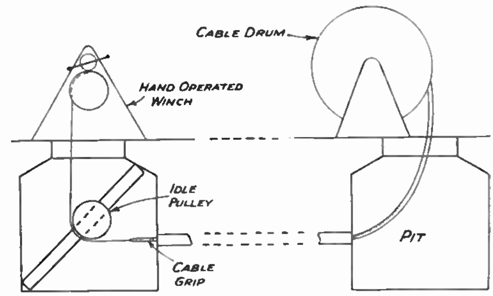
the cable and grips the lead sheath tighter as the pull on the rope increases.

Precautions with Heavy Cables.

With heavy cables there is a danger of the lead sheathing being drawn partly off the cable or broken or damaged in other ways. To avoid this, the cores of the cable may be sweated into a special socket or lug which is attached to the rope and thus the cable cores take the strain directly.

Mounting a Drum.

The position for mounting a drum for running off cable into a pit is shown in the sketch. The bending of the cable should be as little as possible, and the larger the radius of the bend the better for the cable. Plain lead covered cable is invariably used for draw-in systems, and it should be coated with a suitable lubricant such as vaseline as it enters the duct mouth.

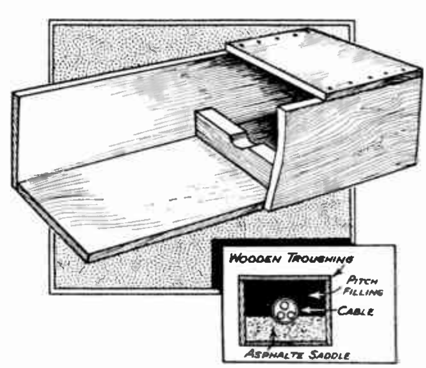


How the Drum is Mounted.
This shows the position for mounting a drum for running off cables into a pit.

A labourer should be specially detailed off to look after the cable as it is being fed into the duct mouth, and to grease the lead liberally during this process. Another labourer should be placed at the top of the pit, from which position he can give instructions to the men handling the drum, and keep an eye on the progress of the cable into the duct. At the next pit to that at which the drum is mounted there will be a gang of perhaps 15 men pulling the rope attached to the cable. To assist them to pull together the ganger may have a small whistle which he will blow about every 4 seconds.

When to Use a Winch.

With very heavy cables it may be necessary to use a winch in order to draw the cable through the ducts. The winch is mounted immediately above the manhole and the wire rope is carried round an



Section of Wood Troughing.

PARTIALLY FILLED-IN CABLE TRENCH.
Showing .25 sq. in. three-core 6,000-volt cable with interlocked warning tiles for protection.

idle pulley and then through the duct on to the cable. The idle pulley is about 2 ft. in diameter and its position in the pit is adjustable so that its bottom bearing surface is in line with the duct mouth. The sketch illustrates this point and shows both the pit into which the cable is being fed and the adjoining pit some 100 yards or so away where the winch is mounted. If hand drawing is resorted to, the pulling-in gang will take the place of the winch. Where the ducts are fairly deep, it may be necessary to break away one side of the pit to enable the gang to get a more direct pull.

Advantages of the Conduit System.

The conduit system is extensively used in the centres of large towns for feeder cables. It is rarely used for distributor cables, where services have to be connected every few yards, and has nothing to recommend it for this purpose. As the load on a network grows, it is a very simple and inexpensive matter to draw out an old cable and draw into the vacated duct a larger size of cable. The system is, therefore, very flexible. Cables in ducts will not, however, carry as much current for the same increase of temperature as cables laid direct, but the advantages in the directions indicated are so real that they are a great asset to large cable systems in towns.

LAYING CABLES DIRECT—SYSTEM (C).

Ground is excavated to a depth of 18 in. in the footpath, the trench being about 15 in. wide, and the bottom is levelled and cleared of sharp stones. The cable is then placed in position in the bottom of the trench and about 3 in. of sifted earth is filled in. Protective tiles are now placed along the trench immediately in line with the cable, these tiles being interlocked to prevent displacement. The ground may then be filled in and well rammed down. The proportion of men engaged on punning the loose soil ought

DRAWING A .5—.25—.5 SQ. IN. THREE-CORE LEAD-COVERED AND ARMOURED LOW TENSION CABLE ALONG CABLE TRENCH, SUPPORTED BY ROLLERS.

to be twice as many as those engaged in shovelling this soil into the cutting. Some undertakings use creosoted wood boards as a warning of the presence of a cable, but it would appear that hard burnt clay tiles have a much longer life. These tiles have letters cut into their surface indicating the presence of a cable beneath them. Thus in the photograph shown, the tile bears the inscription 6 kv. ELECTRICITY, which informs any subsequent excavator of the proximity of a 6,000-volt cable, and ensures the cautious use of pickaxes.

Drawing the Cable Along the Trench.

When laying cables in a footpath entirely free from obstruction, it is possible to run all the cable off the drum and lay it bodily in the trench. More frequently, however, there are numerous gas and water services crossing the trench.

Threading the Cable Under Obstructions.

Then it becomes necessary to thread the cable under these obstructions. The use of rollers placed in the trench for cable to rest upon speeds up this work, and enables longer lengths of heavy cables to be pulled in than would otherwise be possible. The cable drum is mounted on jacks at a convenient position at the side of the trench, and a "stocking" cable grip, as shown in the photograph, is attached to a stout rope, and also to the end of the cable. Three men are detailed off to attend to the rotating of the drum, whilst others pull on the rope and feed the cable into the trench. As the cable travels over the rollers along the trench, other men stand straddle in the bottom of the trench and each holds a rope sling which passes beneath the cable . As a signal from the ganger the men pull on the rope slings and the cable moves along the trench a yard or so. The men now move their slings forward and the procedure is repeated. The rollers are placed at 15 ft. intervals.

Take Care Not to Damage Other Pipes.

Usually it is not advisable to excavate for a greater distance than 100 yards at a time. Great care should be taken not to damage gas or water pipes, and any damage should be reported at once to the ganger in charge who will immediately notify the proper authorities. Cables from which services are to be taken should be laid about 2 ft. 6 in. from the property line, where possible, and should be at least 6 in. from gas mains. Where cable is laid through "made" ground such as ashes, clinker, etc., it will be necessary to bring clay from some other place and surround the cable with this to prevent corrosive action. Alternatively, the cable may be laid solid through bad patches of ground.

Armoured Cable.

Usually all cable laid direct is of the armoured type the armouring consisting of double steel tapes which overlap each other. These tapes are wound over a layer of tarred jute, which provides a bedding between the lead sheath and the armouring. A similar bedding is laid over the armour and this is white-washed to prevent the coils of cable sticking to each other on the drum.

The Mangnall Irving Thrust Borer.

Where a road has to be crossed it is often possible to avoid excavating the roadway. The Mangnall Irving Thrust Borer enables one to do this. Two holes are excavated on opposite sides of the road which it is desired to cross. A special mechanism similar to an hydraulic ram is lowered into one hole and adjustments are made to line up the ram with the hole across the road. Rods are now connected to the piston of the ram and hydraulic pressure applied to one side of the piston which forces the rods through the earth in the required direction. The pump for maintaining the water under pressure is mounted on the footpath or roadway outside the pit, and the high pressure water conveyed by flexible tubing to the ram below.

CORRESPONDENCE

The Editor invites correspondence from readers on any subject of general interest to electrical engineers. Letters should be addressed to THE EDITOR, The Practical Electrical Engineer, 8-11, *Southampton Street, Strand, W.C.*2.

Scale Models for Electrical Testing.

SIR,—A. J. T. (Wembley) raises an interesting point in your first number; interesting in more ways than one because the world of models is at all times extraordinarily fascinating, but I think the answer to your correspondent's question is: No; models will not help.

To use water as an analogy (as is done so often in electrical work), your readers will probably still have fresh in their minds Kaye Don's feat in *Miss England III.* Before this boat was built, experiments were carried out with scale model, rocket-driven hulls, in an endeavour to ascertain various points.

At least one authority has subsequently definitely stated that with the speeds achieved, further improvement can only be reached by experimenting with full-size craft. As with the boat, so with the switchgear, and the chief difficulty would appear to be the resistance, since, if a quarter-scale model were made, its insulation values would not be a fourth of those in the full-size gear.

L. R. L. (STROOD).

The Diesel Electric Generator.

SIR,—Your correspondent A.P.Q. (Yeovil), on the subject of "Diesel Electric Generation," quotes the "all in" cost of .6d. per unit as being the practicable figure for a typical small works plant of 100 K.W. capacity.

I should be obliged if he would itemise it under the following headings:—

Wages (running)	Per Unit Generated.
Fuel	,, ,, ,,
Lubricating oil ..	,, ,, ,,
Stores and water	,, ,, ,,
Maintenance ..	,, ,, ,,
Interest on capital	,, ,, ,,
Depreciation ..	,, ,, ,,

Insurance, rent, rates, taxes and a proportion of management expenses per unit generated.

In arriving at the above costs, the annual load factor should be taken as 30 per cent., which represents that of the average factory, while the running plant load factor would be about 70 to 75 per cent. G.H. (HAROLD WOOD).

Will J.Y. (Motherwell), whose letter appeared in the October issue, please forward his full address. (ED.).

Printed in Great Britain for the Proprietors, GEORGE NEWNES, LTD., 8-11, Southampton Street, Strand, W.C. 2, by Williams, Lea & Co., Ltd., Clifton House, Worship Street, E.C. 2. Sole Agents: Australasia: Gordon & Gotch (Australasia), Ltd. South Africa: Central News Agency, Ltd.